Elements of Mechanical Engineering

Subject Code: 15EME14/15 EME 24 IA Marks: 20
Hours/Week: 04 Exams. Hours: 03
Total Hours: 50 Exams. Marks: 80

Course Objectives:

Students belonging to all branches of Engineering are made to learn certain fundamental topics related to mechanical engineering so that they will have a minimum understanding of mechanical systems, equipment and process.

Module - 1

Energy Resources: Non-renewable and renewable energy resources, Petroleum based solid, liquid and gaseous fuels, Calorific values of fuels, Combustion and combustion products of fuels,

Solar Power: Solar Radiation, Solar constant (definition only), Solar Thermal energy harvesting, ex: liquid flat plate collectors, solar ponds (principle of operation only), Solar photovoltaic principle. **Wind Power:** principle of operation of a typical windmill. **Hydro Power:** Principles of electric power generation from hydro power plants, **Nuclear Power:** Principles of Nuclear power plants, **Bio Fuels:** introduction to bio fuels, examples of various biofuels used in engineering applications, Comparison of biofuels with petroleum fuels in terms of calorific value and emission.

Steam Formation and Properties: Classification of boilers, Lancashire boiler, Babcock and Wilcox boiler, boiler mountings and accessories (No sketches for mountings and accessories), wet steam, saturated and superheated steam, specific volume, enthalpy and internal energy. (No numerical problems in this module) **10 Hours**

Module- 2

Turbines and IC Engines and Pumps

SteamMturbines – Classification, Principle of operation of Impulse and reaction turbines, Delaval's turbine, Parson's turbine. (No compounding of turbines).

Gas turbines: Classification, Working principles and Operations of Open cycle and closed cycle gas turbines.

Water turbines- Classification, Principles and operations of Pelton wheel, Francis turbine and

Kaplan turbine

Internal Combustion Engines

Classification, I.C. Engines parts, 2 Stroke and 4 stroke Petrol engines, 4 stroke diesel engines. P-V diagrams of Otto and Diesel cycles. Problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency, and specific fuel consumption
[**Numerical on IC Engines]** **10 Hours**

Module -3

Machine Tools and Automation
Machine Tools Operations:

Turning, facing, knurling, Thread cutting, Taper Turning by swivelling the compound rest, Drilling, Boring, Reaming, Tapping, Counter Sinking, Counter Boring, -Plane milling, End milling, Slot milling. (No sketches of Machine tools, sketches to be used only for explaining operations. Students to be shown the available machine tools in the Machine Shop of the college before explaining the operations)

Robotics and Automation:
Robotics: Introduction, classification based on robots configuration; Polar, cylindrical, Cartesian

Coordinate and spherical. Application, Advantages, and disadvantages

Automation: Definition, types –Fixed, Programmable & Flexible automation, NC/ CNC machines:

Basic elements with simple block diagrams, advantages and disadvantages. **10 Hours**

Module - 4

Engineering materials and joining processes:
Engineering Materials: Types and applications of Ferrous & Nonferrous metals and alloys, Composites: Introduction: Definition, Classification and applications (Air craft and Automobiles)

Soldering, Brazing and Welding:

Definitions, classification and method of soldering, Brazing and welding. Differences between

soldering, Brazing and Welding. Description of Electric Arc Welding and Oxy-Acetylene Welding. **10 Hours**

Module – 5

Refrigeration, Air-Conditioning

Refrigerants: properties of refrigerants, list of commonly used refrigerants. Refrigeration –

Definitions – Refrigerating effect, Ton of Refrigeration, Ice making capacity, COP, Relative COP, unit of Refrigeration. Principle and working of vapor compression refrigeration and vapour absorption refrigeration: Principles and applications of air conditioners, Room air conditioner.

10 hours

Course outcomes:
Students shall demonstrate the Knowledge associated with,

1. Various Energy sources, Boilers, Prime movers such as turbines and IC engines, Refrigeration and air-conditioning systems

2. Metal removal process using Lathe, drilling, Milling Robotics and Automation.

3. Fair understanding of application and usage of various engineering materials.

Scheme of examination:
• Two full questions (with a maximum of four sub questions) of twenty marks each to be set from each module. Each question should cover all the contents of the respective module.

• Students have to answer five full questions choosing one full question from each module

Text Books:
1. V.K.Manglik, “Elements of Mechanical Engineering”, PHI Publications, 2013. (Module-1, 2, 4, 5)

2. Mikell P.Groover, “Automation, Production Systems & CIM”, 3rd Edition, PHI (Module -3)

3. K.R.Gopalkrishna, “A text Book of Elements of Mechanical Engineering”-Subhash Publishers, Bangalore. (Module -1, 2, 3, 4, 5)

Reference Books:
1. S.TrymbakaMurthy, “A Text Book of Elements of Mechanical Engineering”, 4th Edition 2006, Universities Press (India) Pvt Ltd, Hyderabad.

2. K.P.Roy, S.K.Hajra Choudhury, Nirjhar Roy, “Elements of Mechanical Engineering”, Media Promoters & Publishers Pvt Ltd,Mumbai,7th Edition,2012

3. Pravin Kumar, “Basic Mechanical Engineering”, 2013 Edition, Pearson.

CONTENTS

Module - 1

Energy Resources

There are nine major areas of energy resources. They fall into two categories: nonrenewable and renewable. Nonrenewable energy resources, like coal, nuclear, oil, and natural gas, are available in limited supplies. This is usually due to the long time it takes for them to be replenished. Renewable resources are replenished naturally and over relatively short periods of time. The five major renewable energy resources are solar, wind, water (hydro), biomass, and geothermal.

Since the dawn of humanity people have used renewable sources of energy to survive wood for cooking and heating, wind and water for milling grain, and solar for lighting fires. A little more than 150 years ago people created the technology to extract energy from the ancient fossilized remains of plants and animals. These super-rich but limited sources of energy (coal, oil, and natural gas) quickly replaced wood, wind, solar, and water as the main sources of fuel.

Fossil fuels make up a large portion of today's energy market, although promising new renewable technologies are emerging. Careers in both the renewable and nonrenewable energy industries are growing; however, there are differences between the two sectors. They each have benefits and challenges, and relate to unique technologies that play a role in our current energy system. For a range of reasons, from the limited amount of fossil fuels available to their effects on the environment, there is increased interest in using renewable forms of energy and developing technologies to increase their efficiency. This growing industry calls for a new workforce.

Renewable Energy sources: Defined as the energy resources which are produced continuously in nature and are essentially inexhaustible at least in the time frame of human societies.

1. Ex: Direct solar energy
2. Wind energy
3. Tidal energy
4. Hydel energy
5. Ocean thermal energy

Non-Renewable Energy sources: defined as the energy resources which have been accumulated over the ages and not quickly replenish able when they are exhausted.

1. Ex: Fossil fuels
2. Nuclear fuels

NUCLEAR FUELS

- ❖ Alternative source of energy.
- ❖ Uranium is the main element required to run a nuclear reactor.
- ❖ Nuclear fission or fusion will produce tremendous amount of heat energy.

Nuclear fusion: Fusion energy is a form of nuclear energy released by the fusion (combustion) of two light nuclei (i.e. nuclei of low mass) to produce heavier mass.

$$4\,{}_1H^1 \rightarrow 2He^4 + 2\,{}_{+1}e^0$$

Nuclear fission:

$${}_{92}U^{235} + {}_0N^1 \rightarrow {}_{56}Ba^{137} + {}_{56}Kr^{97} + 2\,{}_0N^1 + \text{Energy}$$

- Nuclear fission is the process, where a heavy nucleus splits into two fragments of more or less of equal mass.

- Neutron + Heavy nucleus → Fission fragments + Neutrons (2 to 3) + energy
- The energy released by fission of I gram of U-235 is equal to that due to combustion of 50 million tons of coal ; it is about 8.5 x 10^{10} J.

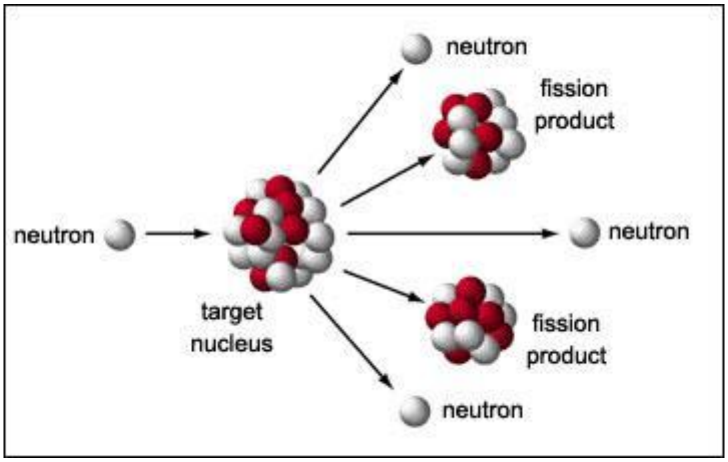


Figure 1: Nuclear fission

NUCLEAR REACTOR

- A nuclear reactor is a device which controls the nuclear fission chain reaction to hardness nuclear energy for peaceful purposes.
- A nuclear reactor which is used t generate electricity, is called a nuclear power plant.
- Fuel in the form of pellets is enclosed in several tubular claddings of steel or aluminum. This is called fuel assembly. Enriched U-235 or Pu-239 is the fuel material.
- A coolant is circulated through the reactor to remove the heat generated. Ordinary water is most commonly used coolant.
- Rods made of boron or cadmium which are neutron absorbers are used as control rods. The neutrons available for fission are controlled by moving the control rods in and out of the nuclear core. The rods can be used to shut down the reactor.

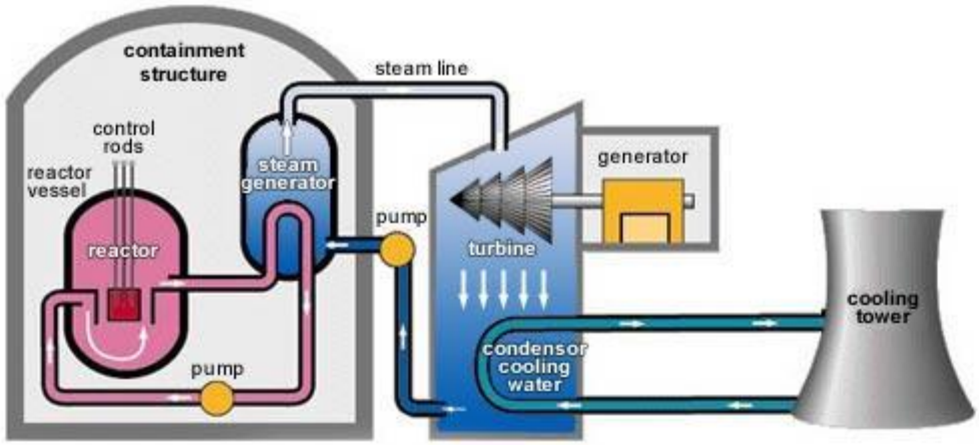


Figure 2: Nuclear reactor

- Heat produced during fission process is absorbed by the coolant and is used to convert water in to steam in the heat exchanger. The steam is used to rotate the steam turbine. The steam turbine is connected to a generator which generates electricity.
- The entire reactor is enclosed in a concrete building with lead sheets covered inside to prevent radioactive radiations being released in to the environment.

Steam Formation and Properties:

Steam Boilers:

Steam boiler is a closed vessel, which is used to convert water into steam at required temperature and pressure by the application of heat.

Classification of Boilers:

1) Horizontal, vertical or inclined
2) Fire tube boiler & water tube boiler
3) Internally fired & externally fired boiler
4) Forced circulation & natural circulation
5) High pressure boiler & low pressure boiler
6) Single tube & multi tube boiler
7) Stationary & portable (locomotive) boiler

Lancashire Boiler:

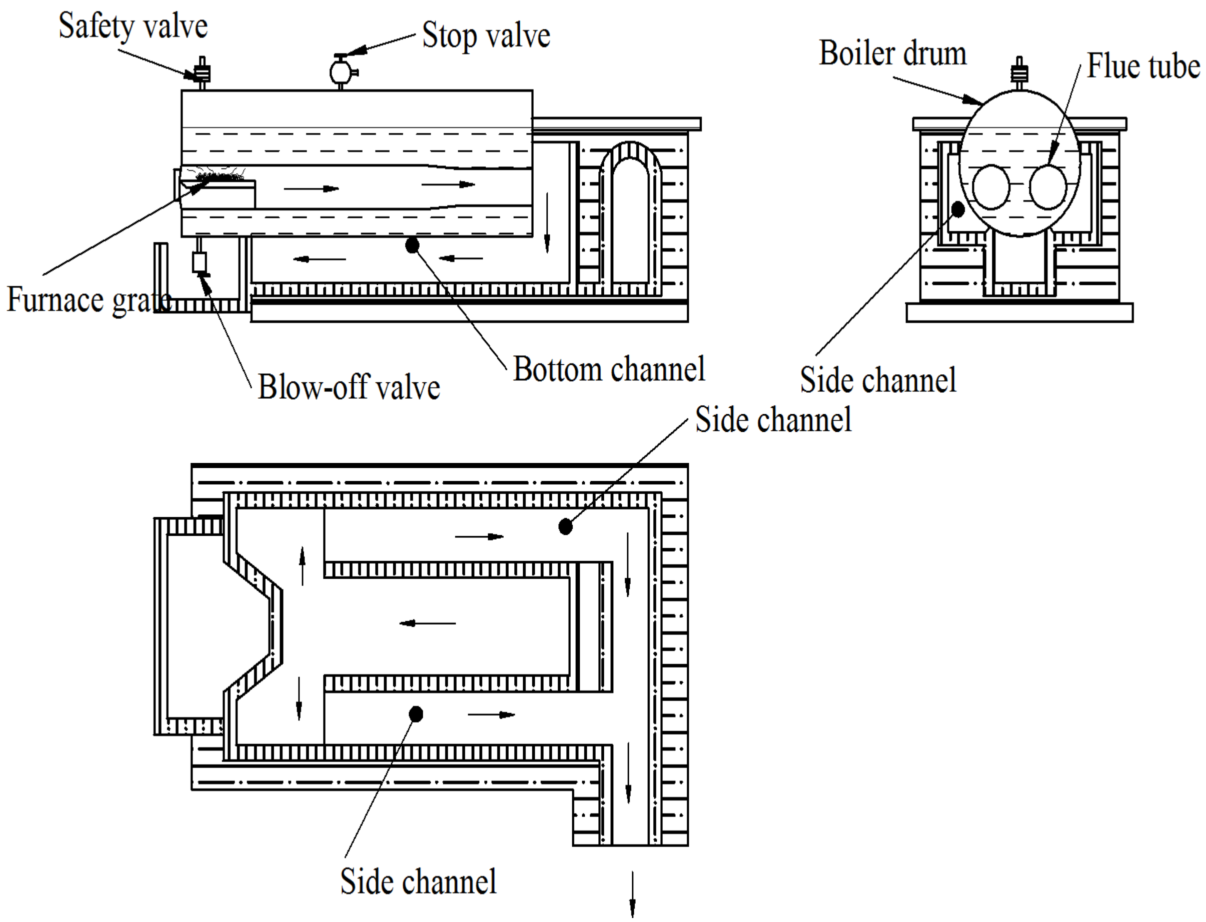


Figure :Lancashire Boiler

Babcock & Wilcox Boiler:

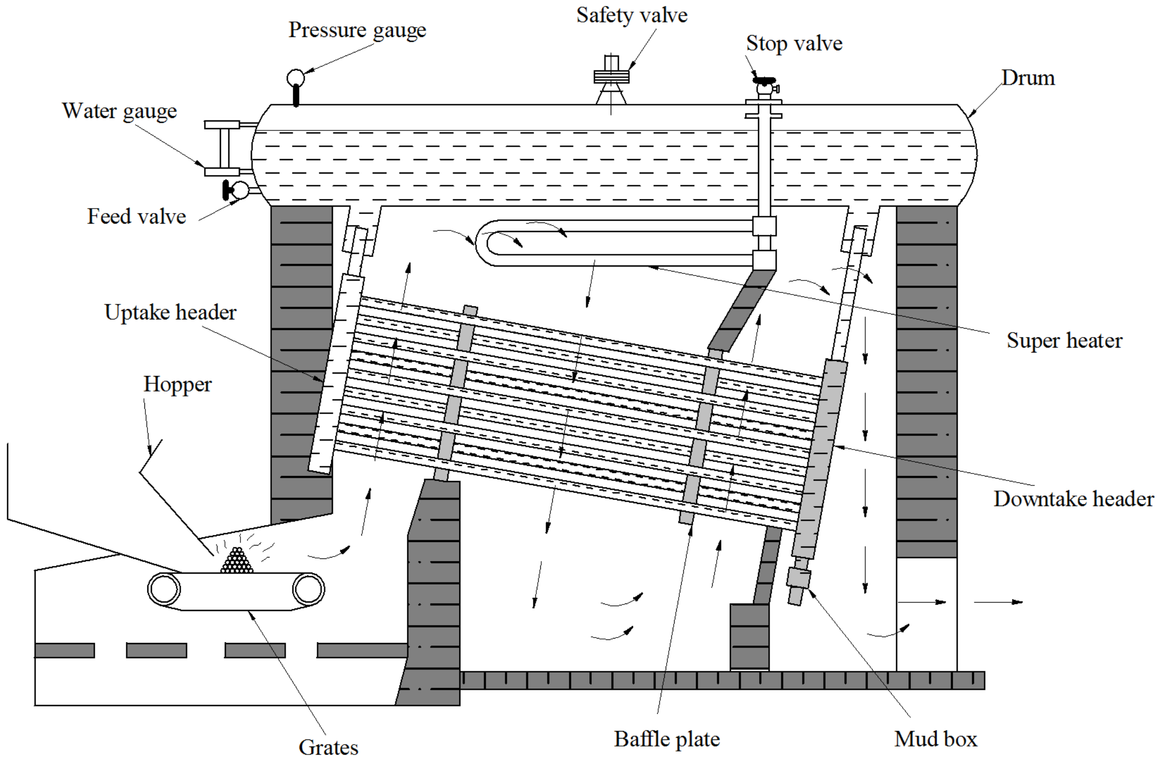


Figure :Babcock & Wilcox Boiler

Boiler mountings:

The boiler mountings are necessary for the proper function & safety of a boiler.

- Safety valve
- Water level indicator
- Pressure gauge
- Blow off valve
- Steam stop valve
- Feed check valve

Boiler accessories:

Boiler accessories are auxiliary parts used in steam boilers for their proper functioning and to improve the efficiency of the power plant.

- Super heater
- Economizer
- Air pre-heater

- Steam separator
- Steam trap

Module- 2

Turbines and IC Engines and Pumps

A turbine is a rotary engine that extracts energy from a fluid flow. The simplest turbine will have one moving part, a rotor assembly with blades attached to it, moving fluid acts on the blades or the blades react to the flow so that they rotate and impart energy to the rotor.

Steam turbines:

1. Impulse turbines
2. Impulse-reaction turbines

<u>Impulse Steam turbine</u>:

- The turbine consists of a series of curved blades fixed on the circumference of a single wheel called rotor which in turn is connected to a shaft
- The high pressure and low velocity steam generated in the boiler is used as a working fluid. The working fluid contains potential energy and kinetic energy
- Before reaching the turbine the fluid's potential energy gets changed to kinetic energy by accelerating the fluid through a nozzle
- The high velocity steam leaving the nozzle is directed towards the moving blades of the turbine
- The steam flowing over the blades undergoes a change in its velocity and direction thereby resulting in change of momentum
- This resulting impulse force pushes the blade in the same direction

  Example: Delaval's Turbine

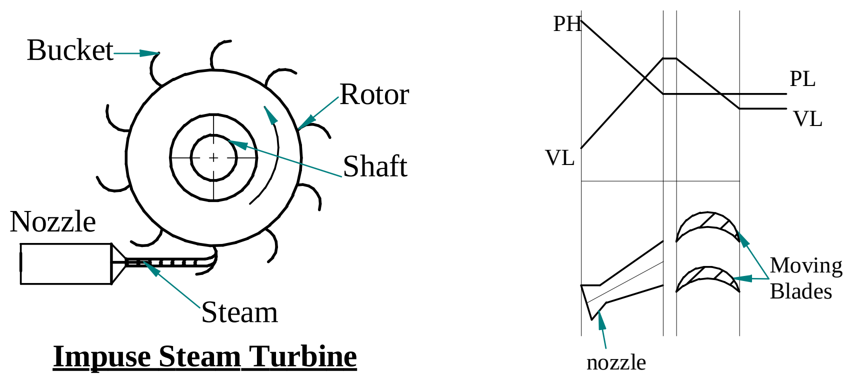


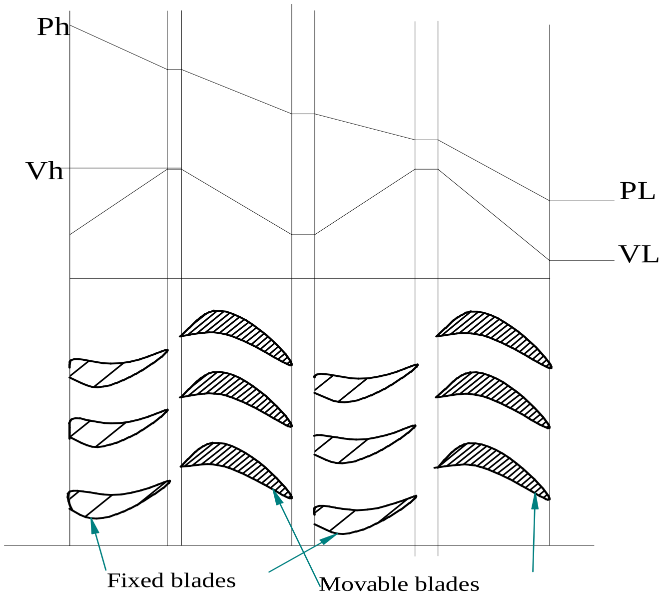
Figure 2.1 Impluse steam turbine

Reaction turbine (Impulse-Reaction Turbine):

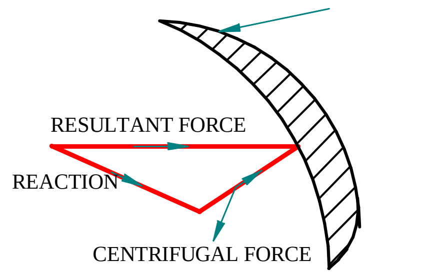
The turbine runs by the reactive force of the jet of steam rather than the direct push or impulse as in case of impulse turbine. It consists of several alternate rows of fixed and moving blades. The fixed blades are fastened to a stationary casing, while the moving blades are mounted on the periphery of a rotating wheel called rotor which in turn is connected to a shaft. In reaction turbine the shape and the cross-section of moving and fixed blades are designed such that it acts as a nozzle.

Working

- The high pressure, low velocity steam generated in a boiler first passes over the fixed blade
- The fixed blade acts as a nozzle where the steam gets expanded to a low pressure and high velocity and it also guides the steam onto the moving blades where it undergoes a change in its velocity and direction thereby resulting in impulse force
- The kinetic energy of the steam is converted into mechanical energy by the rotation of the rotor and when the steam leaves the moving blade, a reactive force is set up



Reaction Turbine



FORCE DIAGRAM FOR REACTION TURBINE

Figure 2.2 Reaction steam turbine

Gas turbines:

It is a thermal prime mover, which utilizes the heat energy of the burnt gases to obtain power.

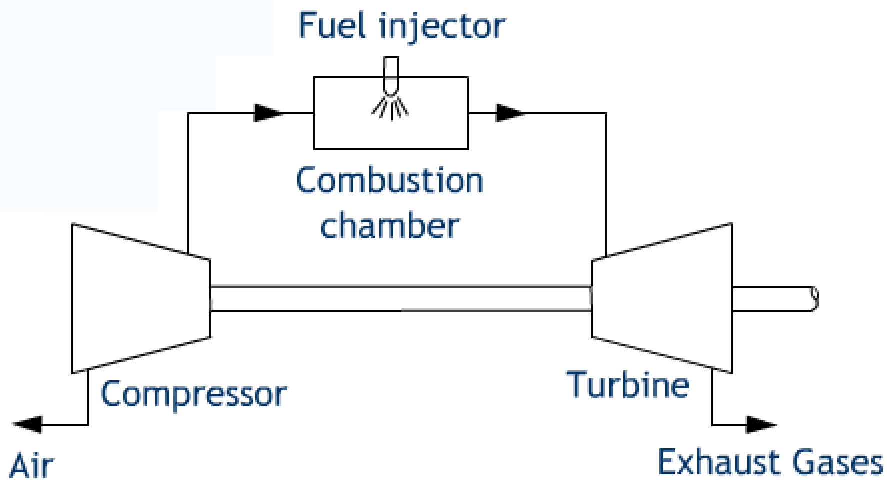
Classification:

a. Open cycle gas turbine
b. Closed cycle gas turbine

Open cycle gas turbine:

It consists of a compressor, a combustion chamber and a turbine. Both turbine and the compressor are mounted on the same shaft.

- The compressor draws air from the atmosphere and compresses it o a high pressure
- The compressed air flows into the combustion chamber where the fuel is burnt at constant pressure
- The high pressure-high temperature hot gases are then made to flow through the turbine blades where heat energy gets converted into mechanical work
- The shaft of the turbine in turn will be connected to a generator for producing electricity
- The gases coming out from the turbine are discharged to the atmosphere, hence called as open cycle gas turbine

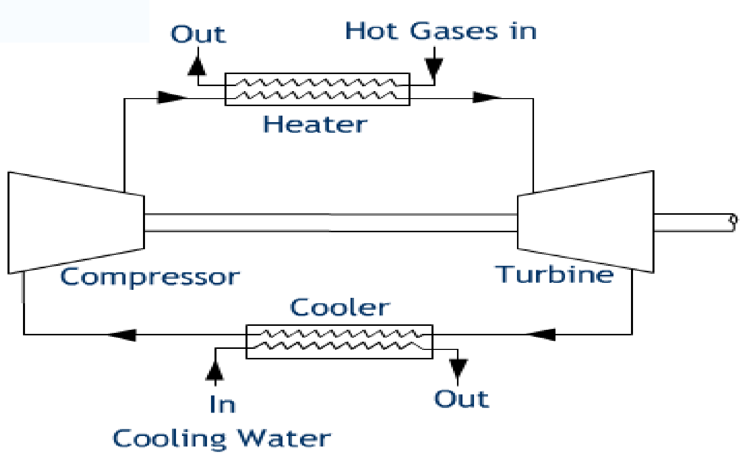


Open cycle Gas turbine

Closed cycle gas turbine:

It consists of a compressor, a heater, a turbine and a cooler. The compressor and turbine are mounted on the same shaft. Gases like argon, helium, nitrogen, carbon dioxide are used as working fluid for turbines.

- The working fluid is compressed in a compressor and passed on to a heater where it gets heated and the heat is transferred using an heat exchanger
- The high pressure and temperature fluid is made to flow through the turbine
- After expansion of hot gases, heat energy will get converted to mechanical work
- The fluid is then made to pass through a cooler and the low temperature and pressure fluid is made to pass to a compressor for the next cycle
- Since the working fluid is circulated again and again, hence it is called as closed cycle gas turbine



Closed cycle Gas turbine

Water Turbines:

It is a hydraulic prime mover which converts the potential and kinetic energy of water into mechanical energy in the form of rotation of shaft.

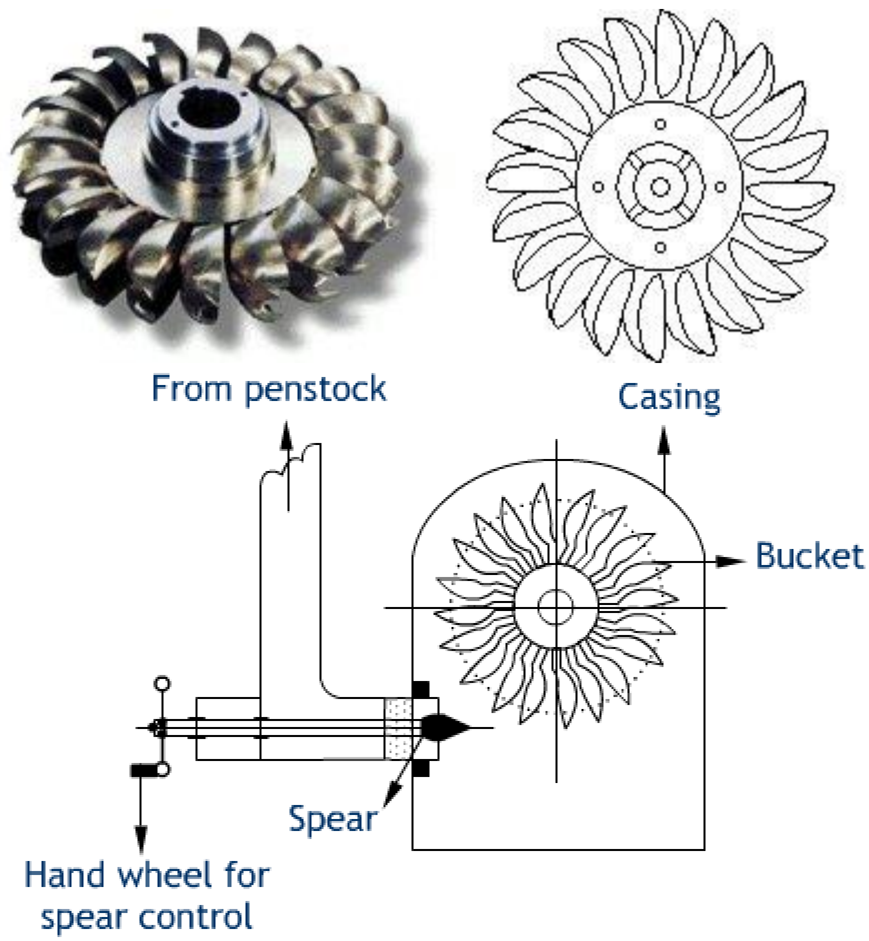
Classification of Water turbines:

1. **Type of energy available at the inlet**
    a. **Impulse turbine**: only kinetic energy is available at the inlet of the turbine. Example- Pelton wheel
    b. **Reaction turbine**: both pressure and kinetic energy are available at the inlet of the turbine. Example- Kaplan, Francis turbine.
2. **Head at the inlet of the turbine**
    a. **High head turbine**: Head of water available at the inlet of turbine. It ranges from 100 to 1000 meters. Example- Pelton wheel
    b. **Medium head turbine**: Head of water available at the inlet ranges from 50 to 400 meters Example- Francis turbine.
    c. **Low head turbine**: Head of water available at the inlet will be less than 50 meters Example- Kaplan turbine.
3. **Based on the direction of flow of water through the runner**
    a. **Tangential flow turbine**: Water flows tangential to the runner. Example- Pelton wheel
    b. **Axial flow turbine**: water flows parallel to the axis of rotation of the runner. Example- Kaplan turbine.
    c. **Radial flow turbine**: water flows in radial direction through the runner. Example- Thomson turbine.

Pelton wheel:

- It is a tangential flow impulse turbine used for high heads and small quantity water flow
- Water from the high head reservoirs is supplied to the nozzle provided with a needle which controls the quantity of water flowing out of the nozzle
- As the water flows through the nozzle the potential energy is converted to kinetic energy

- The high velocity jet of water from the nozzle is made to impinge on the curved blades known as Pelton cups fixed around the runner
- The impulsive force of the high velocity jet of water sets the runner into rotary motion and the shaft coupled to the runner also rotates

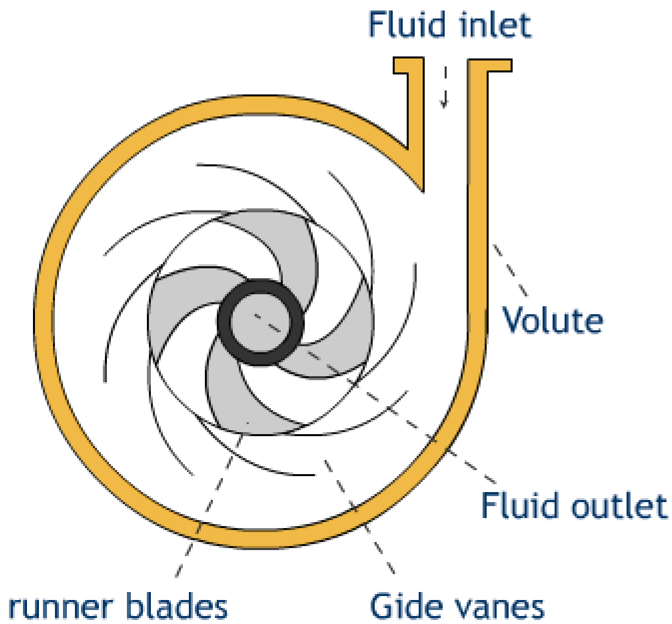


Pelton wheel turbine

<u>Francis Turbine</u>

- It is a medium head reaction turbine in which water flows radially inwards
- It consists of a spiral casing used to distribute water uniformly around the runner
- Water from the reservoir enters the spiral casing and flows radially inwards to the outer periphery of the runner through the guide blades and finally discharged to the tail race axially from the centre of the runner via a draft tube

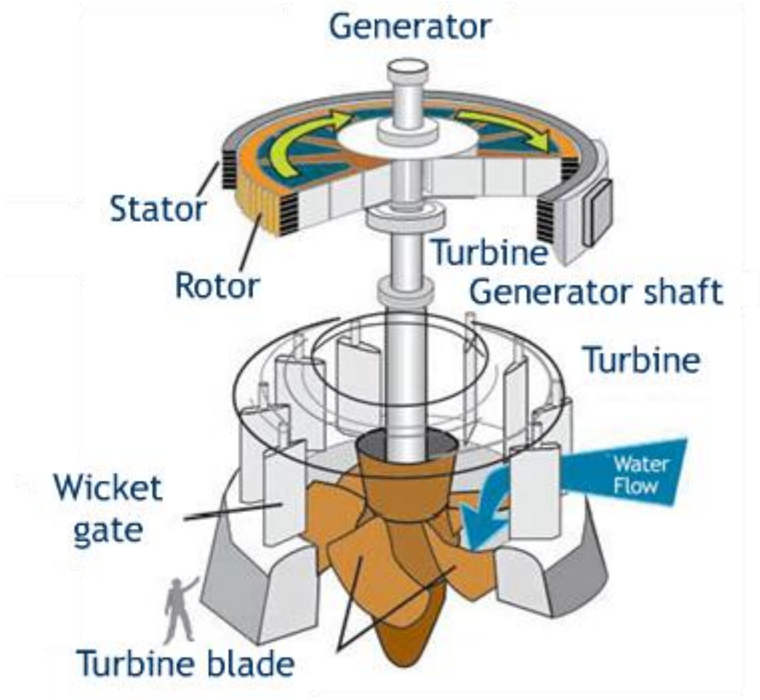
- During its flow over the moving blades it imparts kinetic energy to the energy to the runner to set it into rotational motion. Hence the shaft connected to the runner also rotates thereby doing useful work



Francis Turbine

Kaplan turbine

- It is a low head axial flow section turbine
- The runner of the Kaplan turbine resembles with the propeller of the ship hence it is also called as propeller turbine
- Water from the reservoir flows through the spiral casing where potential energy of water gets converted to kinetic energy
- The water then moves through the guide vanes (blades) and flows axially imparting the kinetic energy to set it into rotational motion
- When the water leaves the blade at high velocity a reaction force is set up and this force rotates the runner thus potential energy of water is converted into mechanical work



Kaplan turbine

Internal Combustion Engines

I C engines is called as internal combustion engine combustion (burning) takes inside the closed chamber. E C engine external combustion engine, burning take place outside the engine.
I C engine it converts heat (thermal, chemical) energy into mechanical energy.

Classification of I C engine:

a) Based on thermodynamic cycle
   (1) Otto cycle (2) Diesel cycle (3) Dual combustion cycle.
b) Based on the fuel
   (1) Petrol (2) Diesel (3) Bi-fuel (4) Gas
c) Based on strokes
   (1) Two stroke (2) Four Stroke
d) Based on the Ignition
   (1) Spark Ignition (2) Compression Ignition
e) Based on number of Cylinders
   (1) Single cylinder (2) multi cylinder

f) Based on the engine placing
   (1) V-engine (2) I or vertical engine (3) Horizontal engine
   (4) Opposed engine (5) Radial engine
g) Based on the cooling systems
   (1) Air cooled (2) Water cooled
h) Based on the application

   (1) Transport (2) Locomotive (3) Marine (4) Power generation
   (5) Agricultural (6) Earth moving

<u>Parts of I C engine</u>:

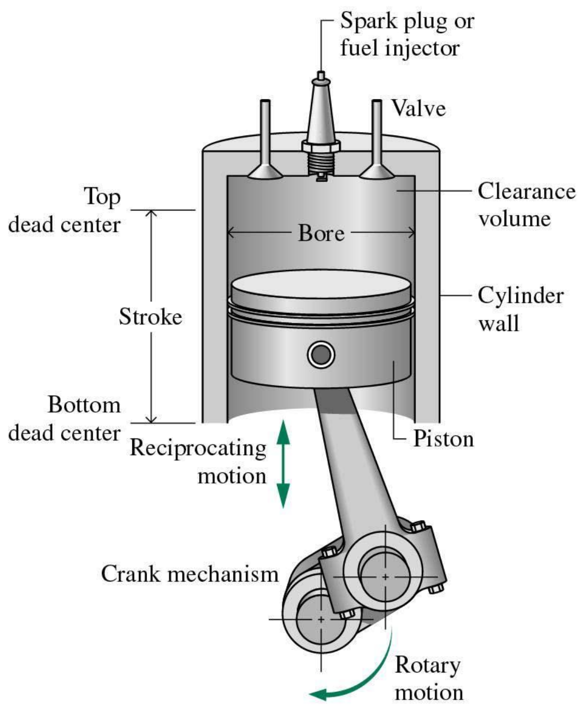


Figure :Parts of IC engine

1) Cylinder: is the heart of the engine, piston reciprocals inside the cylinder.
2) Piston : is a hallow cylinder
   It is fitted inside the cylinder
   It reciprocates inside the cylinder
   It compresses the charges and transmits the power to crank shaft.
3) Connecting Rod: it connects the piston to crank shaft. To convert reciprocating motion of the piston to rotator motioning of the crank shaft.
4) Crank shaft: it receives the rotary motion from the connection rod.
5) Valves: it controls the air/fuel to enter into the cylinder and also to discharges the exhaust gas. Inlet value air/ fuel is entering

Exhaust value Burnt gases escapes.

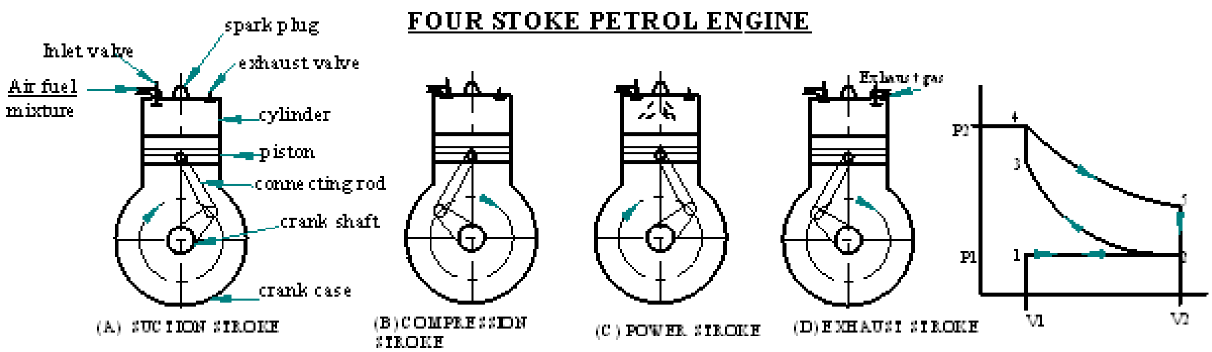
6) Fly wheel: it is fitted at end of the crank shaft.
   It stores the kinetic energy and release the energy to crank shaft.

<u>Some of the notation</u>:

B.D.C: Bottom dead centre
T.D.C: Top dead centre
I.V: Inlet value
O.V: Outlet value or exhaust valve.
Stroke: The piston displacement is called as stroke (T.D.C to B.D.C or B.D.C to T.D.C) 180^o revolution of the crank in 4 strokes.
Bore: Diameter of the inside cylinder.

<u>Four Stroke Petrol Engine (Spark Ignition)</u>:

The following are the working strokes
(A) Suction (B) Compression (C) Power (D) Exhaust stroke.



<u>SUCTION STROKE:</u>

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (crank rotates 0-180^o)
3. Piston sucks the air fuel mixture in to the cylinder (constant pressure and volume increase V1 to V2)

<u>COMPRESSION STROKE:</u>

1. Both inlet and exhaust values closed.
2. Piston moves from bottom dead centre to top dead centre. (180^o to 360^o crank rotation).
3. Pressure and temperature of the air fuel mixture increases. (volume decreases)
4. At the end of compression stroke volume remains constant for a small displacement , it is called constant volume cycle (compression ratio is 1:14)

POWER STROKE:

1. Both inlet and exhaust value closed.
2. High pressure and high temperature air fuel mixture catches the fire with spark plug.
3. High amount energy released and pushes piston down word direction.
4. Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

1. Exhaust value opens and inlet value closed
2. Piston moves from bottom dead centre to top dead centre.
3. The burnt gases escape from the cylinder.
4. Crank shaft completes the two revolutions and generates one power stroke.

FOUR STROKE DIESEL ENGINE (compression ignition)

The following are the working strokes

(A) Suction (B) Compression (3) Power stroke (4) Exhaust

SUCTION STROKE:

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (rank rotates 0-180^o)
3. Piston sucks the fresh air into the cylinder (constant pressure and volume increases) (v1 to v2)

COMPRESSION STROKE:

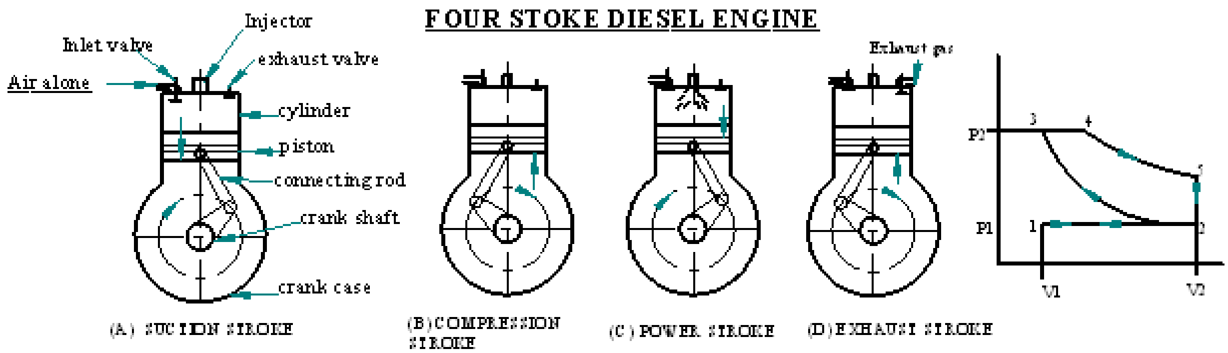
1. Both inlet and exhaust valves closed
2. Piston moves from bottom dead centre to top dead centre (180^o to 360^o rotation)
3. Pressure and temperature of the air increases to high
4. At the end of the compression stroke pressure remains constant for a small displacement of the piston. It is called constant pressure cycle compression (ratio is 1:20)

POWE STROKE:

(1) Both inlet and exhaust value closed.
(2) High pressure and high temperature air catches the fire with diesel is sprayed.
(3) High amount energy released and pushes piston down word direction.
(4) Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

(1) Exhaust value opens and inlet value closed
(2) Piston moves from bottom dead centre to top dead centre.
(3) The burnt gases escape from the cylinder.
(4) Crank shaft completes the two revolutions and generates one power stroke.



Two Stroke Petrol Engine:

1. First Stroke 2. Second Stroke

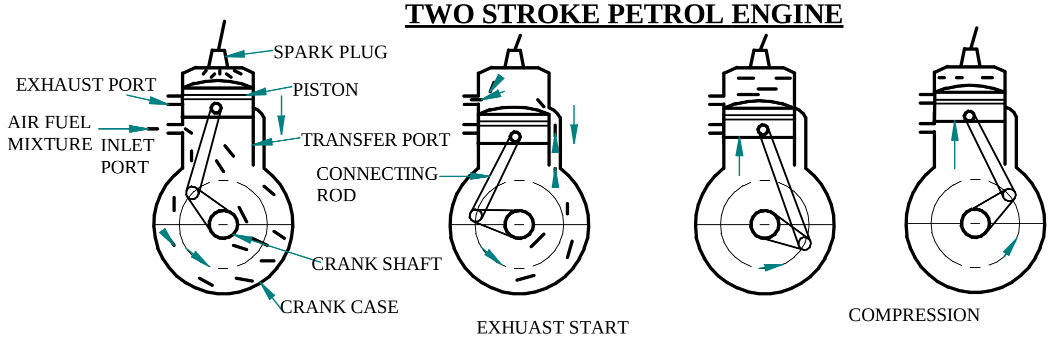
First stroke:

- The spark plug ignites the compressed petrol and air mixture
- The high pressure combustion gases force the piston downwards
- The piston performance the power stroke till it covers the exhaust port
- As soon as piston uncovers the transfer port, the fresh air fuel mixture flows from crankcase in to the cylinder
- This drives out of the exhaust gases by the incoming fresh charge is called scavenging
- Piston moves from top dead centre to bottom dead centre

Second stroke:

- In this stroke piston moves from bottom dead centre to top dead centre
- The piston covers the transfer port; air fuel mixture is cut off, suction stops
- Further movement of the piston will compress the air fuel mixture in the cylinder
- The ratio of compression is from 1:8 to 1:12
- At end of compression stroke air fuel get ignited

TWO STROKE PETROL ENGINE



(a) FIRST STROKE **(b) SECOND STROKE**

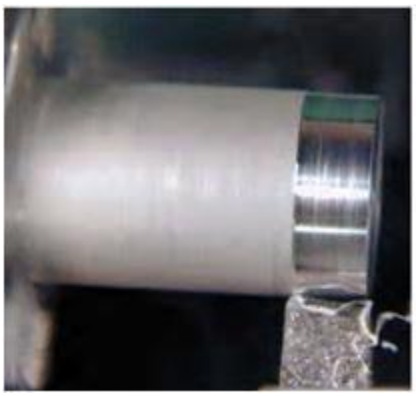
Module -3

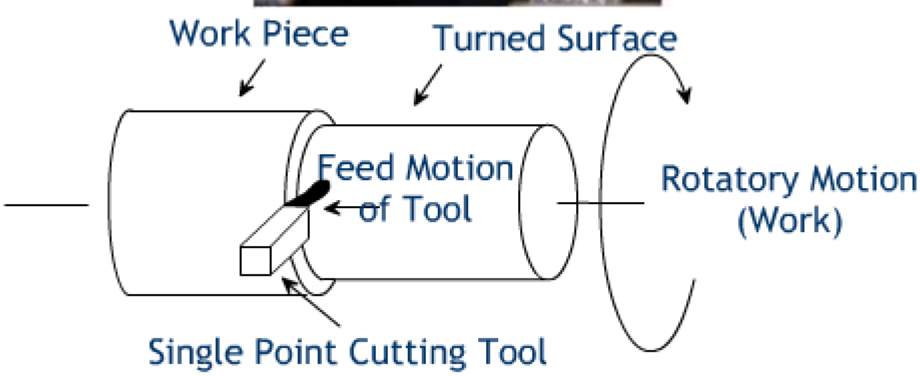
Machine Tools and Automation

Machine Tools Operations:

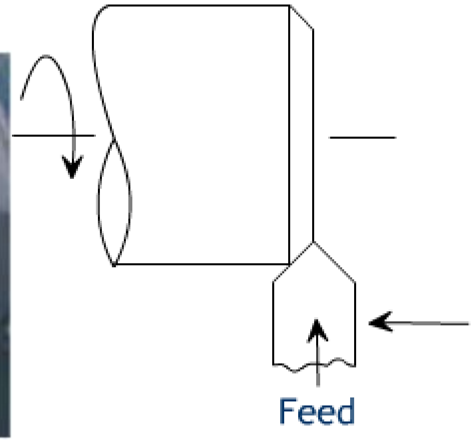
Turning:

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

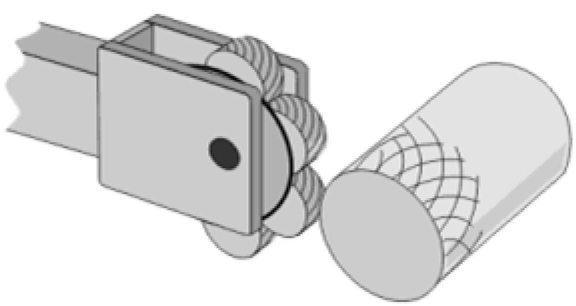


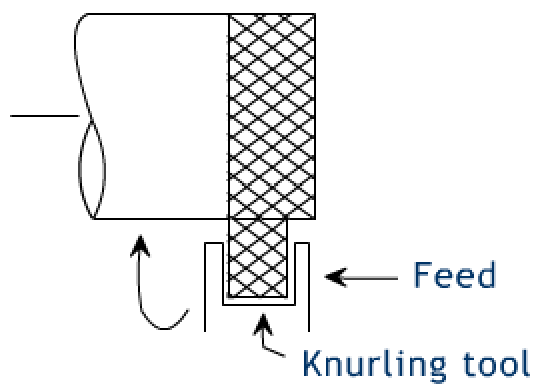


Facing: Facing is the process of removing metal from the end of a work piece to produce a flat surface. It is some time called squaring. The facing tool used is of round edge, if the tool is pointed then the work piece will not have good finishing. The work piece rotates about its axis and the facing tool is fed perpendicular to the axis of lathe. Most often, the work piece is cylindrical, but using a 4-jaw chuck you can face rectangular or odd-shaped work to form cubes and other non-cylindrical shapes.

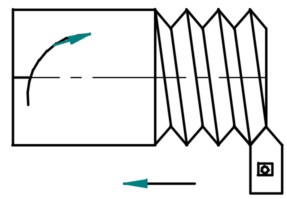


Knurling: It is the process of embossing a required shaped pattern on the surface of the work piece. This diagram shows the knurling tool pressed against a piece of circular work piece. The lathe is set so that the chuck revolves at a low speed. The knurling tool is then pressed against the rotating work piece and pressure is slowly increased until the tool produces a pattern on the work piece.

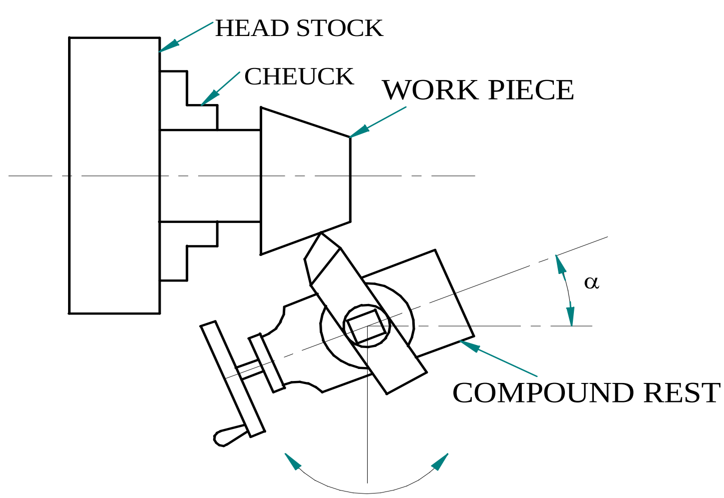




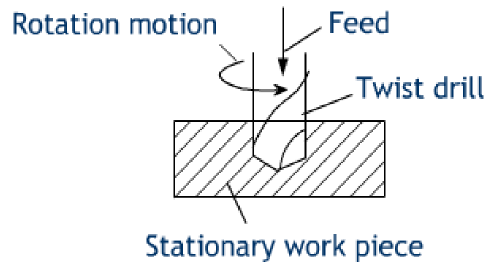
Thread cutting: A thread is a uniform helical groove cut on or in a cylinder or cone. The tool is ground to the shape of the thread and is moved longitudinally with uniform motion. The required pitch can be obtained by maintaining the appropriate gear ratio between the spindle and the lead screw which enables the tool to move longitudinally at appropriate speed.



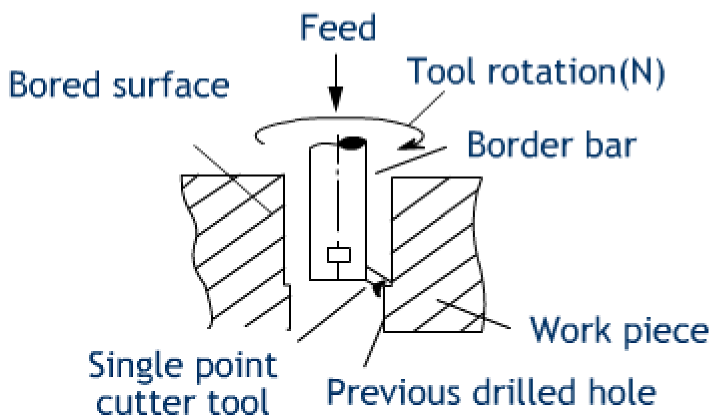
Taper Turning by swivelling the compound rest: In this method of taper the half taper angle is calculated. The compound rest has rotating base graduated in degrees, which can be rotated to any angle (according to the taper angle). In this method the tool is advanced by rotating the compound rest and hand wheel so that the tool moves according to set taper angle. This method produces taper length larger than form tool method.



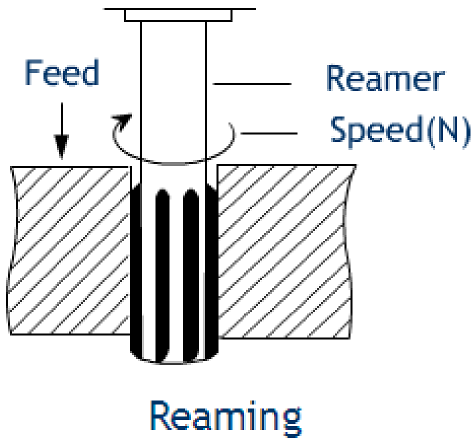
Drilling: The drilling is one of the simplest methods of producing a hole. Before drilling a hole, the center point of the hole has to be marked on the work piece. The center point of the hole is marked by just drawing two cross lines or by using instruments. The mark is indented using a center punch. The hole to be drilled may be a through hole or a blind hole. Through hole can be drilled on any machine, but to drill a blind hole we need a sophisticated machine.



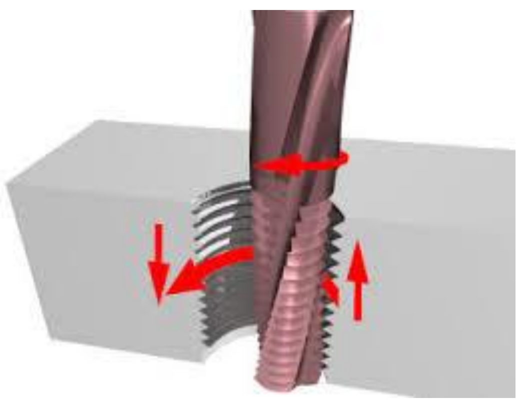
Boring: It is an operation employed to enlarge a hole by means of an adjustable cutting tool with only one cutting edge. This is necessary where suitable sized drill is not available or where the hole diameter is so large that it cannot be ordinarily drilled. It is used to finish a hole accurately and to bring it to the required size. In precision machines the accuracy is as high as 0.00125mm; the process is slower compared to reaming and requires several passes of tool.



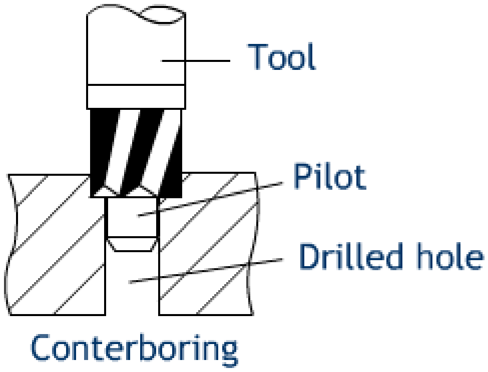
Reaming: Reaming is a sizing and finishing operation performed on a previously drilled hole. The tool used for reaming operation is known as reamer, which has multiple cutting edges. The spindle speed is half compared to drilling operation. Reamers cannot produce hole, but follow the path already defined by the drilling. The metal removed in this process is small, range is about 0.35 mm.



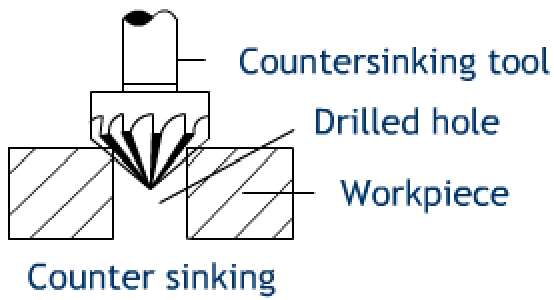
Tapping: Is an operation of cutting internal threads by means of a cutting tool called a ***tap***. A slightly smaller diameter hole is drilled before tapping and a tap is fitted in the tapping attachment which in turn is mounted in the drilling machine spindle.



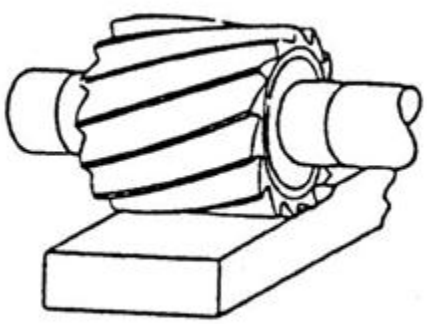
Counter Boring: Is an operation of enlarging the end of a hole cylindrically. The enlarged hole forms a square shoulder with the original hole. The tool is guided by a pilot which extends beyond the end of the cutting edges. The pilot fits into the small diameter hole having running clearance and maintains the alignment of the tool. Counter boring is done to accommodate the heads of bolts, studs, pins etc. Counter boring can give accuracy of about 0.050mm.



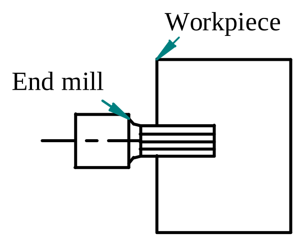
Counter Sinking: Is an operation of making a cone-shaped enlargement of the end of a hole to provide a recess for a flat head screw or countersunk rivet fitted into the hole. The tool used for countersinking is called a countersink. Standard countersinks have 60^0, 82^0 or 90^0 included angle and the cutting edges of the tool are formed at the conical surface.



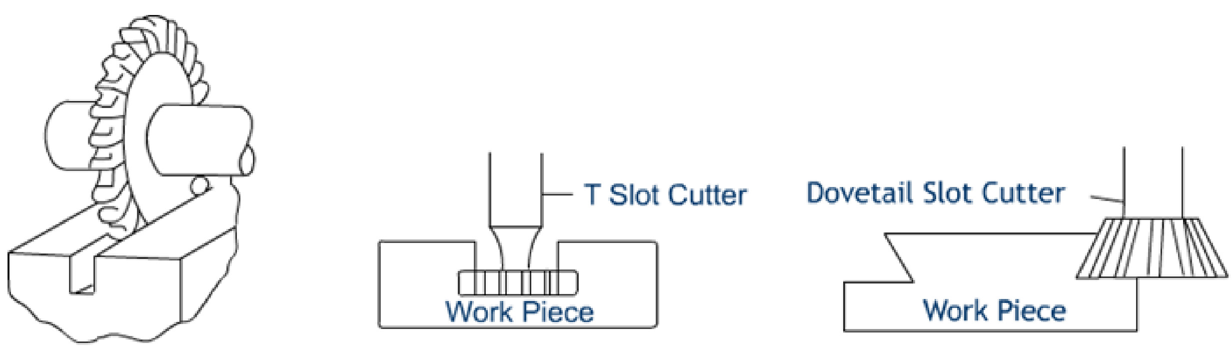
Plane milling: The plain milling is the operation of production of a plain flat horizontal surface parallel to the axis of rotation of a plain milling cutter. The operation is also called slab milling.



End milling: The end milling is the operation of production of a flat surface which may be vertical, horizontal or at an angle in reference to the table surface. Use to produce slots, grooves or key ways.



Slot milling: The process of producing keyways grooves and slots of varying shapes and sizes is known as slotting. The side milling cutter is mounted on to the arbor of a horizontal milling machine when slotting had to be done on Horizontal milling machine. T–Slots and dovetail slots are carried out on a veridical milling machine.



Robotics and Automation:

Introduction

An industrial robot is a general purpose, programmable machine possessing certain anthropomorphic characteristics. The most obvious anthropomorphic characteristic of an industrial robot is its mechanical arm, which is used to perform various industrial tasks. Other human like characteristics are the robot's capabilities to respond to sensory inputs, communicate with other machines, and make decisions. These capabilities permit robots to perform a variety of useful tasks.

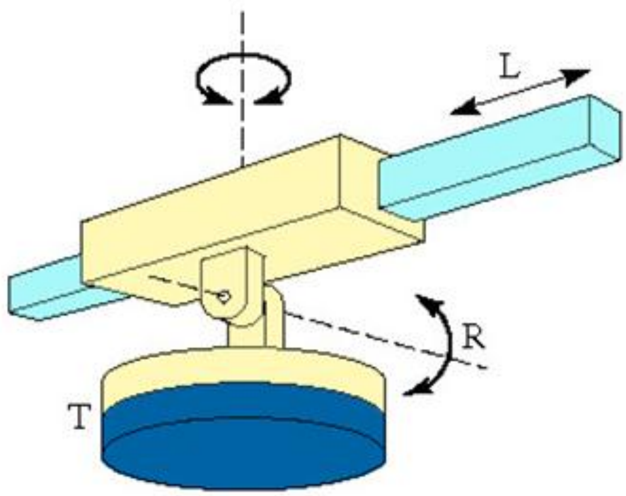
Some of the qualities that make industrial robots commercially and technologically important are listed

- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multi shift operations
- Reprogrammable, flexible
- Interfaced to other computer systems

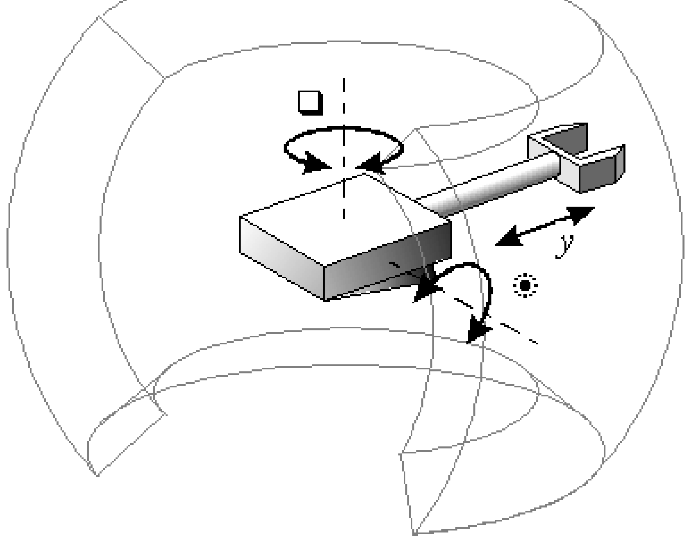
Classification based on robots configuration

- Polar Coordinate
- cylindrical Coordinate
- Cartesian Coordinate

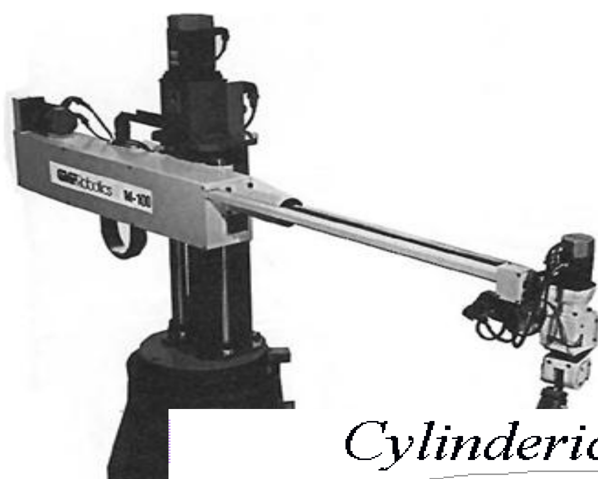
Polar Coordinate: This configuration Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

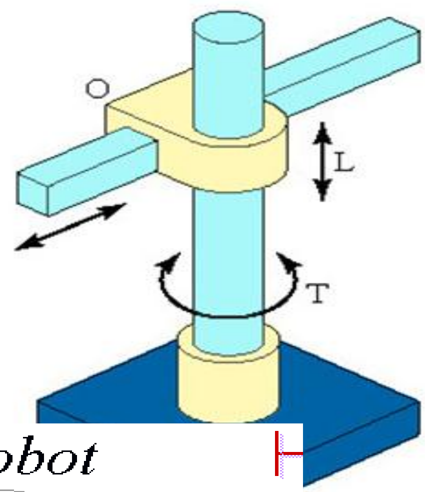


Polar Robot

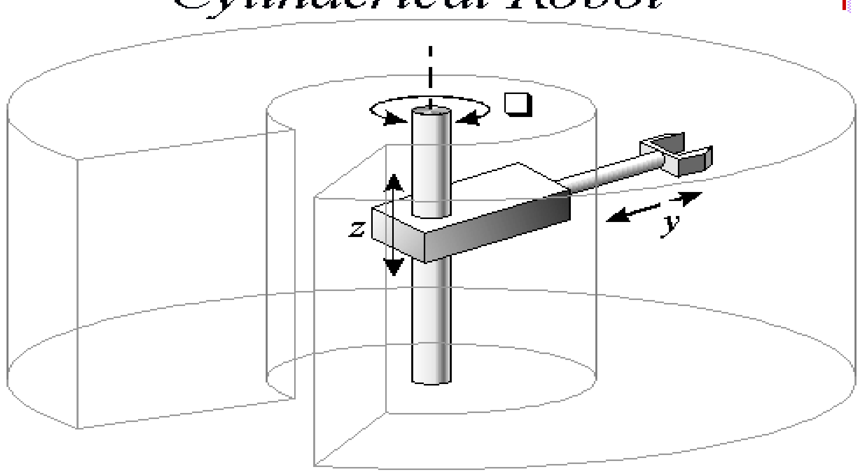


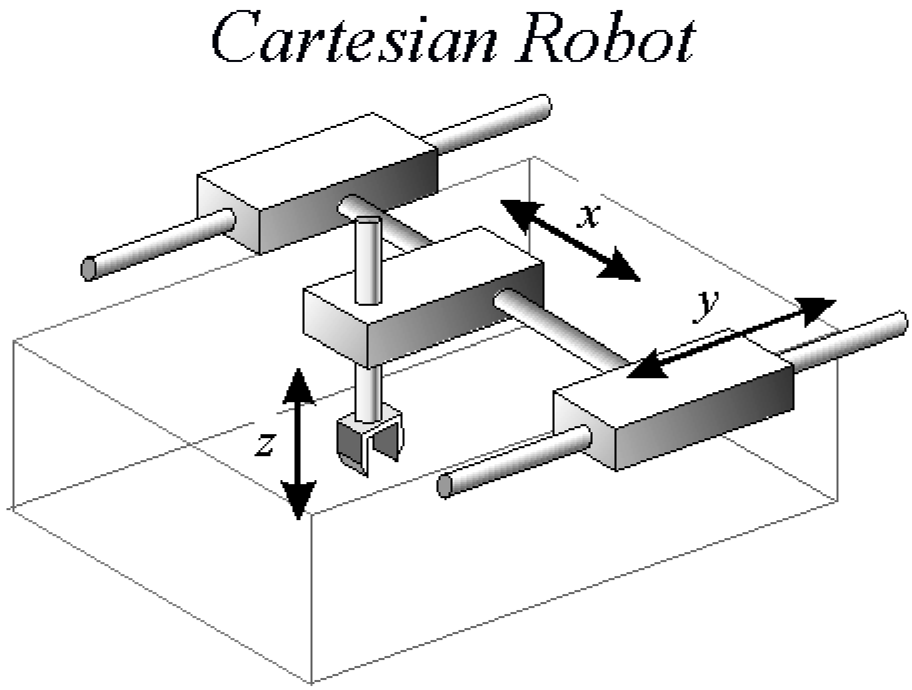
Cylindrical Coordinate: This configuration Consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in or out relative to the axis of the column



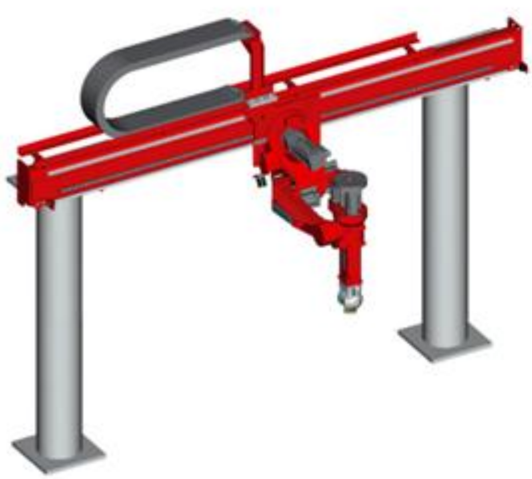


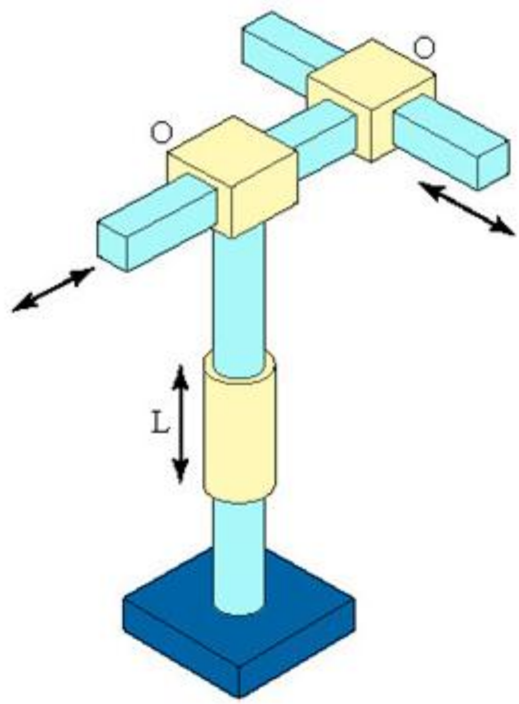
Cylinderical Robot





Cartesian coordinate: Other names for this configuration include rectilinear robot and x-y-z robot. It is composed of three sliding joints, two of which are orthogonal.





Automation:

Automated manufacturing is a manufacturing method that relies on the use of computerized control systems to run equipment in a facility where products are produced. Human operators are not needed on the assembly line or manufacturing floor because the system is able to handle both the mechanical work and the scheduling of manufacturing tasks. The development of fully automated manufacturing systems dates to the later half of the 20th century, and this manufacturing technique is used in facilities of varying scale all over the world.

Automation of production systems can be classified into three basic types:

1. Fixed automation (Hard Automation)

2. Programmable automation (Soft Automation)

3. Flexible automation.

1. Fixed automation (Hard automation): Fixed automation refers to the use of special purpose equipment to automate a fixed sequence of processing or assembly operations. Each of the operation in the sequence is usually simple, involving perhaps a plain linear or rotational motion or an uncomplicated combination of two. It is relatively difficult to accomodate changes in the product design. This is called hard automation.

Advantages:

1. Low unit cost

2. Automated material handling

3. High production rate.

Disadvantages:

1. High initial Investment

2. Relatively inflexible in accommodating product changes.

2. Programmable automation: In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accomodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded. So that they can be read and interpreted by the system. New programs can be prepared and entered into the equipment to produce new products.

Advantages:

1. Flexible to deal with design variations.

2. Suitable for batch production.

Disadvantages:

1. High investment in general purpose equipment

2. Lower production rate than fixed automation.

Example: Numerical controlled machine tools, industrial robots and programmable logic controller.

3. Fixed Automation: (Soft automation): Flexible automation is an extension of programmable automation. A flexible automation system is capable of producing a variety of parts with virtually no time lost for changeovers from one part style to the next. There is no lost production time while reprogramming the system and altering the physical set up.

Advantages:

1. Continuous production of variable mixtures of product.

2. Flexible to deal with product design variation.

Disadvantages:

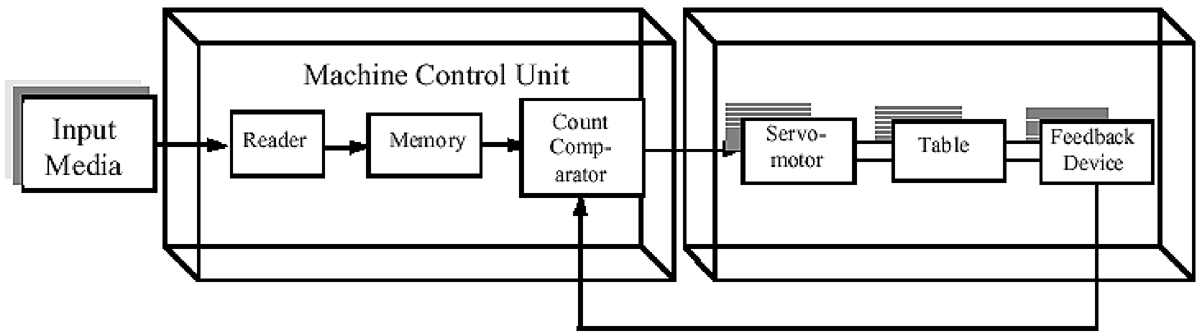
1. Medium production rate

2. High investment.

3. High ‘unit cost relative to fixed automation.

Numerical control (NC):

Numerical Control refers to the method of controlling the manufacturing operation by means of directly inserted coded numerical instructions into the machine tool. It is important to realize that NC is not a machining method; rather, it is a concept of machine control. Although the most popular applications of NC are in machining, NC can be applied to many other operations, including welding, sheet metalworking, riveting, etc.



The major advantages of NC over conventional methods of machine control are as follows:

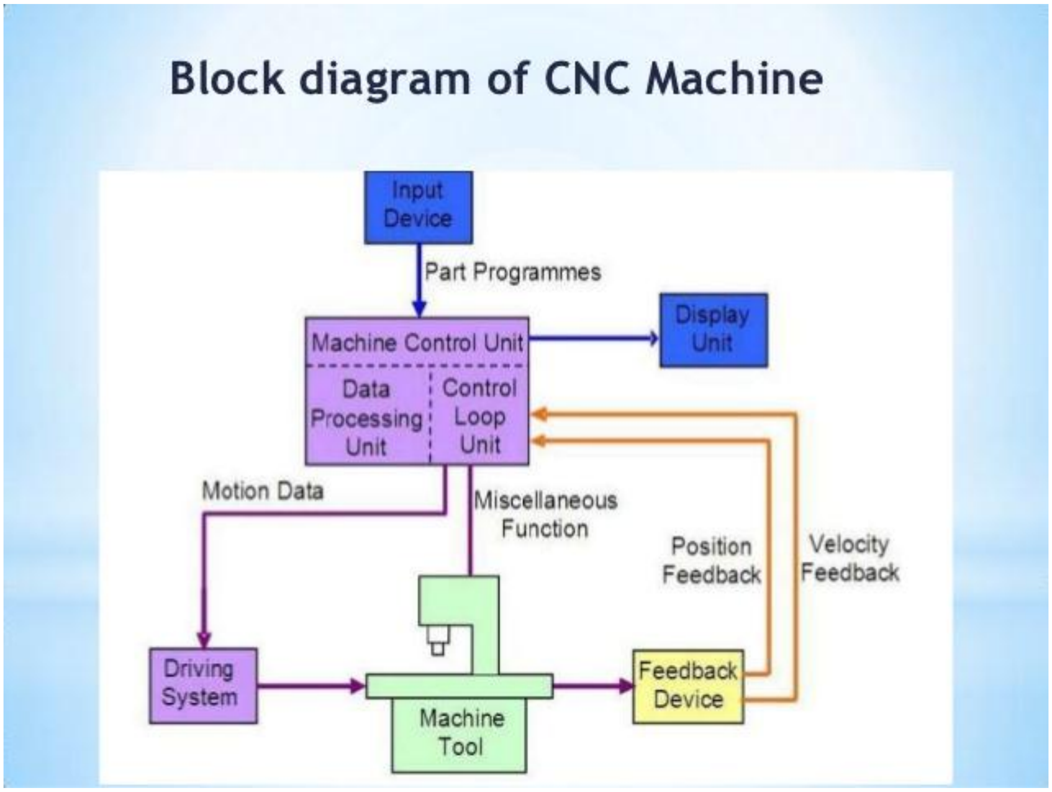
- Higher precision: NC machine tool are capable of machining at very close tolerances, in some operations as small as 0.005 mm;
- Low operator qualification: the role of the operation of a NC machine is simply to upload the work piece and to download the finished part. In some cases, industrial robots are employed for material handling, thus eliminating the human operator.
- Multi-operational machining: some NC machine tools, for example machine centers, are capable of accomplishing a very high number of machining operations thus reducing significantly the number of machine tools in the workshops. Very low operator qualification: the role of the operation of a NC
- Higher productivity: NC machine tools reduce drastically the non machining time. Adjusting the machine tool for a different product is as easy as changing the computer program and tool turret with the new set of cutting tools required for the particular part.
- Better quality: NC systems are capable of maintaining constant working conditions for all parts in a batch thus ensuring less spread of quality characteristics;

The major disadvantages of NC

- Relatively high initial cost of equipment
- Need for part programming
- Special maintenance is required
- More costly breakdown

Computer Numerical Control (CNC):

CNC is a self-contained NC system for a single machine tool that uses a dedicated computer controlled by stored instruction in the memory to implement some or all of the basic NC functions. It is flexible and relatively low-cost.



The major advantages of CNC

- Increased productivity
- High accuracy and repeatability
- Reduced production costs
- Reduced indirect operation costs

- Facilitation of complex machining operations
- Greater flexibility
- Improved production planning and control
- Lower operator skill requirement
- Facilitation of flexible automation

The major disadvantages of CNC

- High initial investment
- High maintenance
- For low production it is costlier process

ROBOTICS

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

The Origins of Robots

Year 1250

Bishop Albertus Magnus holds banquet at which guests were served by metal attendants. Upon seeing this, Saint Thomas Aquinas smashed the attendants to bits and called the bishop a sorcerer.

Year 1640

Descartes builds a female automaton which he calls “Ma fille Francine.” She accompanied Descartes on a voyage and was thrown overboard by the captain, who thought she was the work of Satan.

Year 1738

Jacques de Vaucanson builds a mechanical duck quack, bathe, drink water, eat grain, digest it and void it. Whereabouts of the duck are unknown today.

Year 1805

Doll, made by Maillardet, that wrote in either French or English and could draw landscapes

Year 1923

Karel Capek coins the term *robot* in his play *Rossum's Universal Robots (R.U.R). Robot* comes from the Czech word *robota* , which means "servitude, forced labor."

Year 1940

Sparko, the Westinghouse dog, was developed which used both mechanical and electrical components.

Year 1950's to 1960's

Computer technology advances and control machinery is developed. Questions Arise: Is the computer an immobile robot? Industrial Robots created. Robotic Industries Association states that an "industrial robot is a re-programmable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions to perform a variety of tasks"

Year 1956

Researchers aim to combine "perceptual and problem-solving capabilities," using computers, cameras, and touch sensors. The idea is to study the types of intelligent actions these robots are capable of. A new discipline is born: A.I.

Year 1960

Shakey is made at Stanford Research Institute International. It contained a television camera, range finder, on-board logic, bump sensors, camera control unit, and an antenna for a radio link. Shakey was controlled by a computer in a different room.

The first industrial robot: UNIMATE Year 1954

The first programmable robot is designed by George Devol, who coins the term Universal Automation. He later shortens this to Unimation, which becomes the name of the first robot company (1962).

Year 1978

The Puma (Programmable Universal Machine for Assembly) robot is developed by

Unimation with a General Motors design support

Year 1980s

The robot industry enters a phase of rapid growth. Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.

Year 1995-present

Emerging applications in small robotics and mobile robots drive a second
growth of start-up companies and research

2003

NASA’s Mars Exploration Rovers will launch toward Mars in search of answers about the history of water on Mars

Robot Physical Configuration

Industrial robots come in a variety of shapes and sizes. They are capable of various arm manipulations and they possess different motion systems.

Classification based on Physical configurations

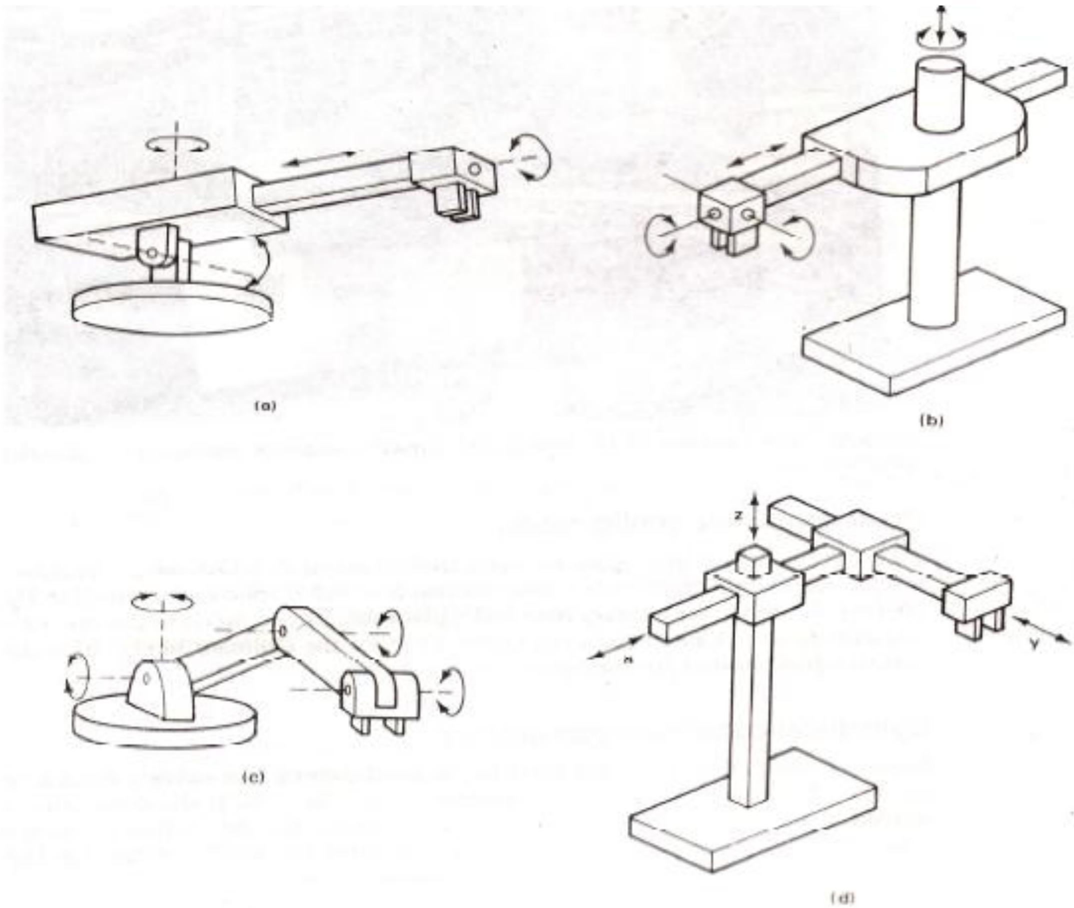
Four basic configurations are identified with most of the commercially available industrial robots

1. Cartesian configuration: A robot which is constructed around this configuration consists of three orthogonal slides, as shown in fig. the three slides are parallel to the x, y, and z axes of the Cartesian coordinate system. By appropriate movements of these slides, the robot is capable of moving its arm at any point within its three dimensional rectangularly spaced work space.

2. Cylindrical configuration: in this configuration, the robot body is a vertical column that swivels about a vertical axis. The arm consists of several orthogonal slides which allow the arm to be moved up or down and in and out with respect to the body. This is illustrated schematically in figure.

3. Polar configuration: this configuration also goes by the name “spherical coordinate” because the workspace within which it can move its arm is a partial sphere as shown in figure. The robot has a rotary base and a pivot that can be used to raise and lower a telescoping arm.

4. Jointed-arm configuration: is combination of cylindrical and articulated configurations. This is similar in appearance to the human arm, as shown in fig. the arm consists of several straight members connected by joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space.



Basic Robot Motions

Whatever the configuration, the purpose of the robot is to perform a useful task. To accomplish the task, an end effector, or hand, is attached to the end of the robots arm. It is the end effector which adapts the general purpose robot to a particular task. To do the task, the robot arm must be capable of moving the end effectors through a sequence of motions and positions.

There are six basic motions or degrees of freedom, which provide the robot with the capability to move the end effectors through the required sequences of motions. These six degree of freedom are intended to emulate the versatility of movement possessed by the human arm. Not all robots are equipped with the ability to move in all sex degrees. The six basic motions consist of three arm and body motions and three wrist motions.

Arm and body motions

1. Vertical traverse: Up and down motion of the arm, caused by pivoting the entire arm about a horizontal axis or moving the arm along a vertical slide.

2. Radial traverse: extension and retraction of the arm (in and out movement)

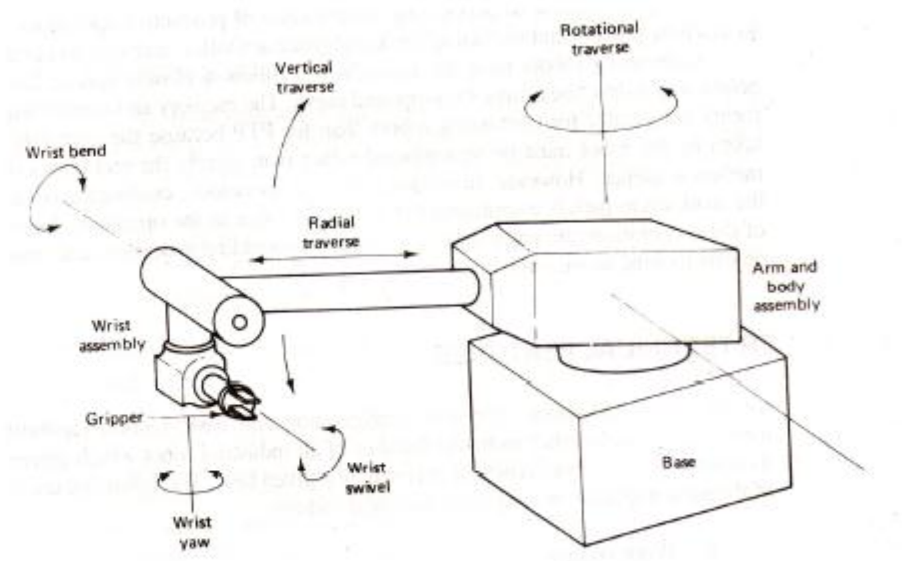
3. Rotational traverse: rotation about the vertical axis (right or left swivel of the robot arm)

Wrist Motion

• Wrist swivel: Rotation of the wrist

• Wrist bend: Up or down movement of the wrist, this also involves rotation movement.

• Wrist yaw: Right or left swivel of the wrist.



Module - 4

Engineering materials and joining processes

All metals may be classified as ferrous or nonferrous. A ferrous metal has iron as its main element. A metal is still considered ferrous even if it contains less than 50 percent iron, as long as it contains more iron than any other one metal. A metal is nonferrous if it contains less iron than any other metal.

Ferrous metals

Ferrous metals contain iron. Examples are cast iron, mild steel, medium carbon steel, high carbon steel, stainless steel, and high speed steel.

Composition, properties and uses of some common ferrous metals

Name	Composition	Properties and characteristics	Principal uses
Cast iron	*Alloy* of iron and 2-5% carbon, 1-3% silicon and traces of magnesium, sulphur and phosphorus.	*Hard* skin, softer underneath, but *brittle*. It *corrodes* by rusting.	Parts with complex shapes which can be made by casting
Mild steel	Alloy of iron and 0.15 - 0.3% carbon	*Tough*, *ductile* and *malleable*. Good *tensile strength*, poor resistance to *corrosion*	General-purpose engineering material
Medium carbon steel	Alloy of iron and 0.35 - 0.7% carbon	*Strong*, hard and tough, with a high tensile strength, but less ductile than mild steel.	Springs; any application where resistance to wear is needed
High carbon steel	Alloy of iron and carbon: 0.7 - 1.5% carbon	Even harder than medium carbon steel, and more brittle. Can be heat-treated to make it harder and tougher	Cutting tools, mechanical elements
Stainless steel	Alloy of iron and carbon with 16-26% chromium, 8-22% nickel and 8% magnesium	Hard and tough, resists wear and corrosion	Cutlery, kitchen equipment
High speed steel	Alloy of iron and 0.35 - 0.7% carbon (medium carbon steel) with tungsten, chromium, vanadium, and sometimes cobalt	Very hard, high *abrasion*- and heat-resistance	Cutting tools for machines

Non-ferrous metals

Non-ferrous metals do not contain iron. Some common non-ferrous metals are aluminum, copper, zinc, tin, brass (copper + zinc), and bronze (copper + tin).

Composition, properties and uses of some common non-ferrous metals:

Name	Composition	Properties and characteristics	Principal uses
Aluminium	Pure aluminium (an element)	Good *strength*-to-weight ratio, light, soft, *ductile*, good *conductor* of heat and electricity	Kitchen equipment, window frames, general cast components
Copper	Pure copper (an element)	*Malleable* and ductile, good conductor of heat and electricity, resistant to *corrosion*	Water pipes, electrical wire, decorative goods
Zinc	Pure zinc (an element)	Weak metal, extremely resistant to corrosion	Usually used for coating steel to make galvanised items
Brass	*Alloy* of copper and zinc	Resistant to corrosion, fairly hard, good conductor of heat and electricity	Cast items such as water taps, ornaments
Bronze	Alloy of copper and tin	Fairly strong, malleable and ductile when soft	Decorative goods, architectural fittings
Tin	Pure tin (an element)	Soft, weak, malleable, ductile and resistant to corrosion	Usually used for coating steel to form tinplate

Engineering Materials

Introduction

Materials are an important aspect of engineering design and analysis. The importance of materials science and engineering can be noted from the fact that historical ages have been named after materials. In the customer driven competitive business environment, the product quality is of paramount importance. The product quality has been found to be influenced by the engineering design, type of materials selected and the processing technology employed. Therefore, the importance of materials and their processing techniques cannot be undervalued in today's world. Materials form the stuff of any engineering application or product. It has been found that the engineers do not give adequate attention to this important subject. Moreover, it has not been adequately represented in the course curriculum of various universities. Therefore, it becomes imperative to highlight the importance of engineering materials for all engineers related to the various aspects of engineering applications.

There is a wide variety of materials available which have shown their potential in various engineering fields ranging from aerospace to house hold applications. The materials are usually selected after considering their characteristics, specific application areas, advantages and limitations. The challenge for designers is to select an optimal material suitable for the specific design requirements. The stringent design requirements generally lead to development of new

materials to meet the specific operating conditions and environments. The new materials are developed from the conventional materials by either by the intrinsic or the extrinsic modification. In intrinsic modification, minor alloying or heat treatment is carried out. In extrinsic modification, external reinforcements are added to the parent material to alter its properties in order to meet the specific design requirements.
The engineers are then entrusted with the task of finding suitable techniques which would lead to high quality cost-effective processing of these materials. In order to achieve this objective, it is imperative for all engineers to have a fundamental understanding of the existing materials and their processing techniques. It has been found that there are adequate of courses in the curriculum of various universities where the processing techniques for metals are dealt in detail. The processing of non-metals is usually not covered as a core subject at the under-graduate level and therefore the engineers do not have a fundamental understanding about the processing of important non-metals such as plastics and ceramics. The course has been designed to study the basic nature of different non-metals and the manufacturing processes associated thereof. The various non-metals covered in the course include glasses, ceramics, plastics and different types of composite materials.

Classification and Selection of Materials:

The first module deals with the classification of the engineering materials and their processing techniques. The engineering materials can broadly be classified as:

a) Ferrous Metals
b) Non-ferrous Metals (aluminum, magnesium, copper, nickel, titanium)
c) Plastics (thermoplastics, thermosets)
d) Ceramics and Diamond
e) Composite Materials
f) Nano-materials

Classification of Processing Techniques

The basic aim of processing is to produce the products of the required quality at a reasonable cost. The basic processes can be broadly classified as:

a) Primary Forming Processes

b) Deformative Processes

c) Material Removal Processes

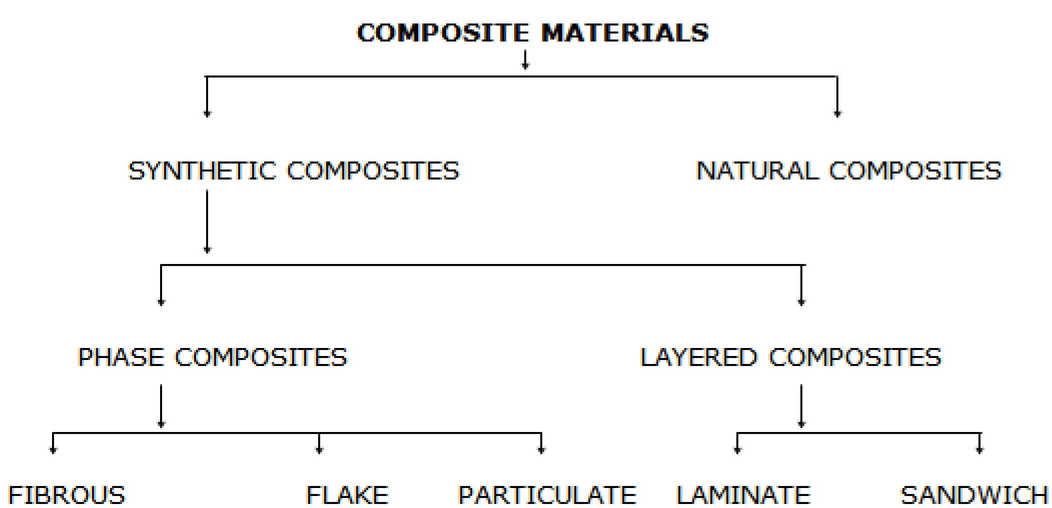
d) Joining Processes

e) Finishing Processes

Most of the engineering materials are processed either individually or in combination by the above mentioned processes. The processes can further be classified as conventional and advanced processes. The specific application area of each will depend on the design requirements and the ability with which a material renders itself to various processing techniques. The selection of a processing technique for any engineering material would broadly depend on the properties (mechanical, physical, chemical) of the material and the required number of parts to be processed.

Composites

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.



Classification of composites I (based on matrix material)

Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and embedded fibers of other ceramic material (dispersed phase).

Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated Polyester (UP), Epoxy (EP)) or thermoplastic (Polycarbonate (PC),Polyvinylchloride, Nylon, Polystyrene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

Classification of composite materials II(based on reinforcing material structure)

Particulate Composites

Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

1. Composites with random orientation of particles.
2. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.

Fibrous Composites

1. Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).
   I. Composites with random orientation of fibers.
   II. Composites with preferred orientation of fibers.
2. Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
   I. Unidirectional orientation of fibers.
   II. Bidirectional orientation of fibers (woven).

Laminate Composites

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.

Composites

Fibers or particles embedded in **matrix** of another material are the best example of modern-day composite materials, which are mostly structural.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. **Fabrics** have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. **Reinforcing materials** generally withstand maximum load and serve the desirable properties.

Further, though composite types are often distinguishable from one another, no clear determination can be really made. To facilitate definition, the accent is often shifted to the levels at which differentiation take place viz., **microscopic** or **macroscopic**.

In **matrix**-based structural composites, the matrix serves two paramount purposes viz., binding the **reinforcement phases** in place and deforming to distribute the stresses among the constituent **reinforcement materials** under an applied force.

The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have **moisture sensitivity** etc. This may offer weight advantages, ease of handling and other merits which may also become applicable depending on the purpose for which matrices are chosen.

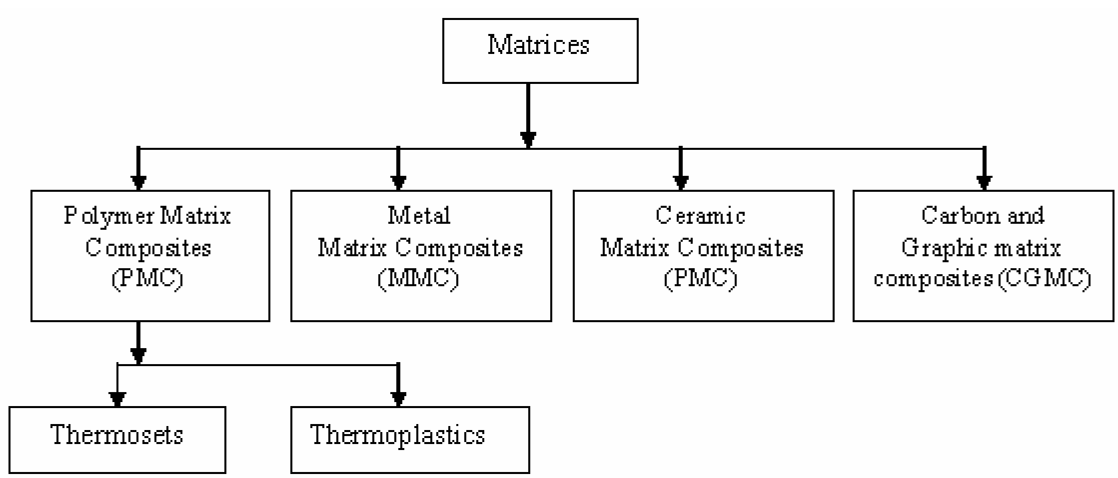
Solids that accommodate stress to incorporate other constituents provide strong bonds for the reinforcing phase are potential **matrix materials**. A few inorganic materials, polymers and metals have found applications as matrix materials in the designing of structural composites, with commendable success. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression.

Classification of Composites

Composite materials are commonly classified at following two distinct levels:

- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

- The second level of classification refers to the reinforcement form - fibre **reinforced composites**, **laminar composites** and **particulate composites**. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres.
- **Fibre Reinforced Composites** are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.
- **Laminar Composites** are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- **Particulate Composites** are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category



Organic Matrix Composites

Polymer Matrix Composites (PMC)/Carbon Matrix Composites or Carbon-Carbon Composites

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications.

Two main kinds of polymers are **thermosets** and **thermoplastics**. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the **chopped fiber composites** form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of **conventional compress techniques** to mould the compounds.

Resins reinforced with thermoplastics now comprised an emerging group of composites. The theme of most experiments in this area to improve the base properties of the resins and extract the greatest functional advantages from them in new avenues, including attempts to replace metals in die-casting processes. In crystalline thermoplastics, the reinforcement affects the **morphology** to a considerable extent, prompting the reinforcement to empower nucleation. Whenever **crystalline** or **amorphous**, these resins possess the facility to alter their **creep** over an extensive range of temperature. But this range includes the point at which the usage of resins is constrained, and the reinforcement in such systems can increase the failure load as well as creep resistance. Figure M1.2.1 shows kinds of thermoplastics

Metal Matrix Composites (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High **strength**, **fracture toughness** and **stiffness** are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

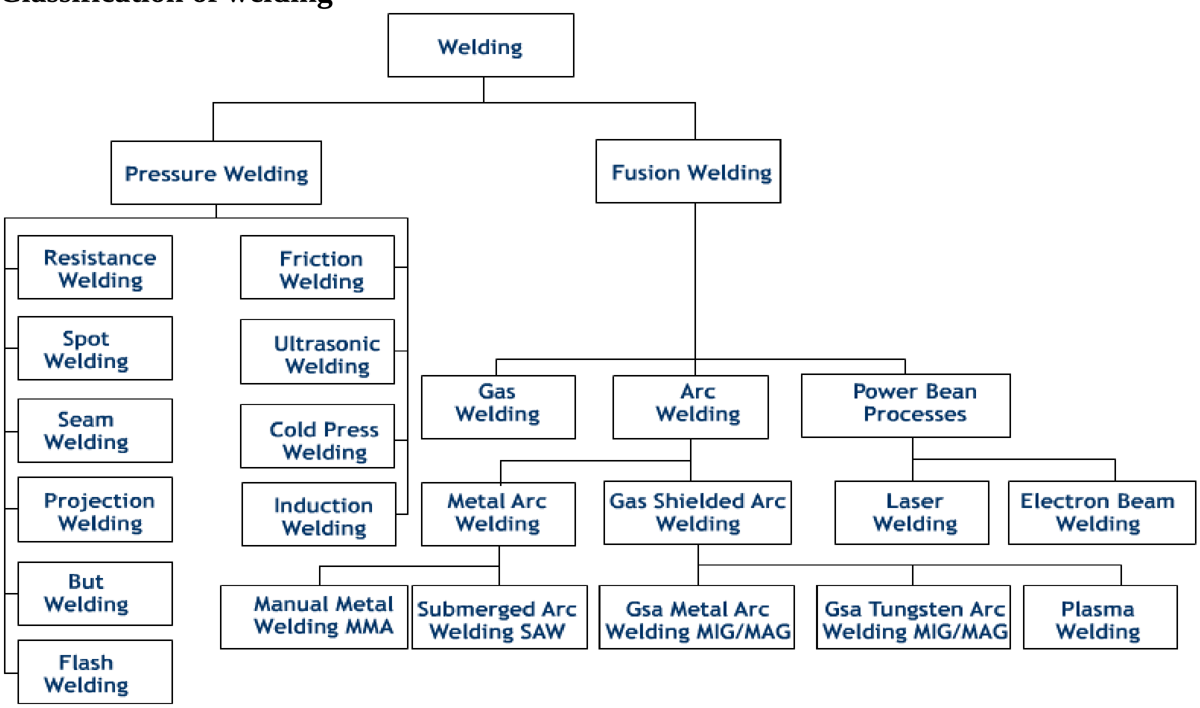
The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

Soldering, Brazing and Welding:

Welding:

Welding is defined as the joining of two metal pieces, together to produce essentially a single piece of metal.

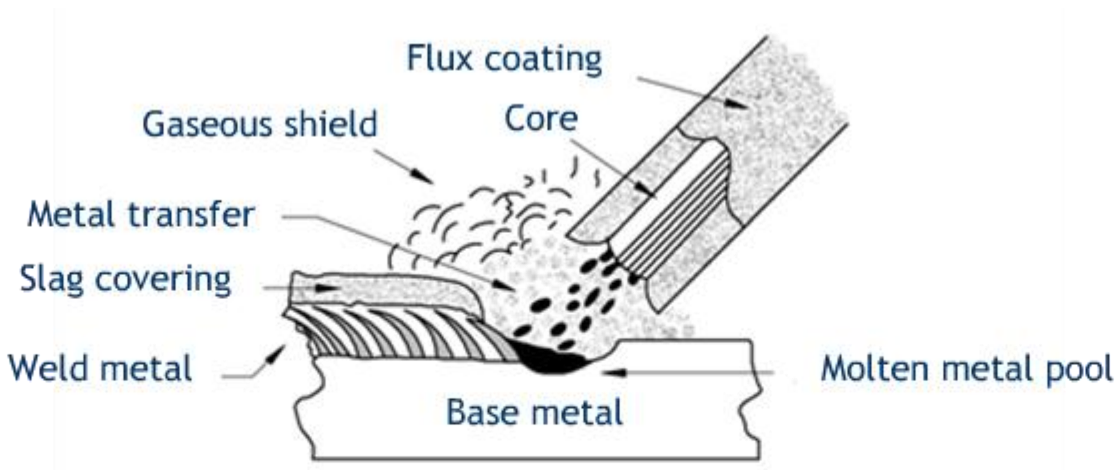
Classification of welding



Types of Welding

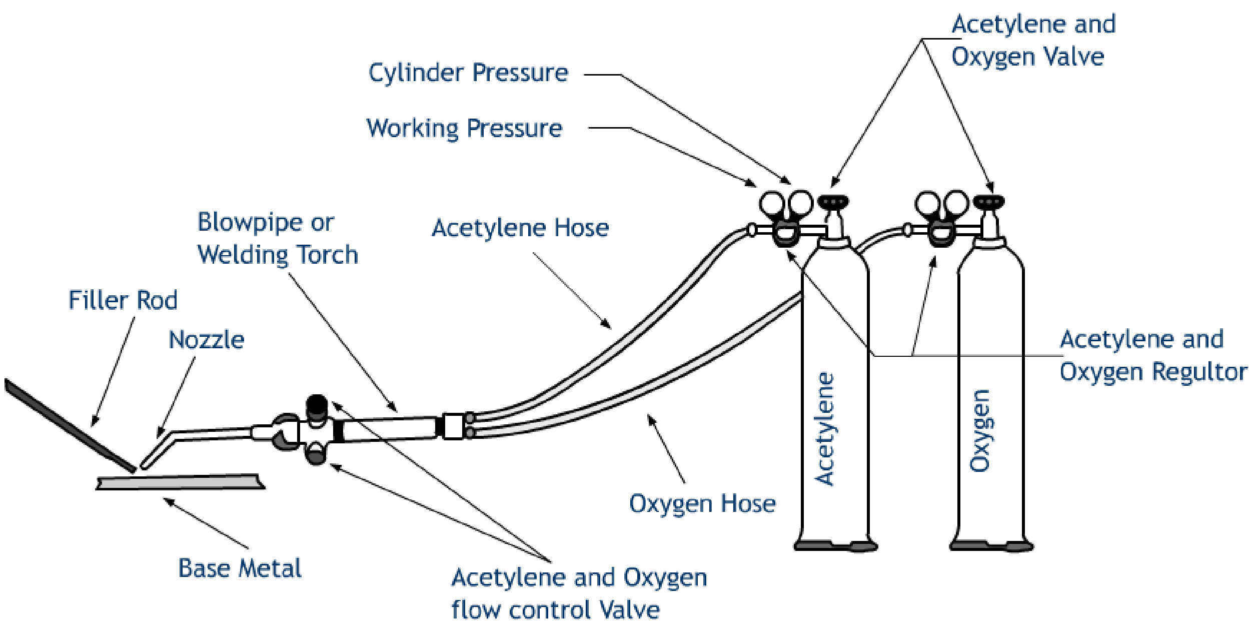
1) **Fusion Welding:** joining two metal pieces is heated up to molten state and allowed to solidify, also called as no-pressure welding.
   Ex- Arc welding and Gas welding
2) **Pressure welding:** joining parts to be heated up to plastic state and applying external pressure.
   Ex- Resistance welding and Forge welding.

Electric Arc Welding



Arc welding is one of several fusion welding processes for joining metals. By applying intense heat through a electric arc, metal at the joint is melted and caused to intermix - directly, or with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts.

Oxy-Acetylene Welding



This is a common gas welding process. Acetylene is the fuel gas used. Acetylene produces high heat content in the range of 3200^0 C than other fuel gases. Acetylene gas has more available carbon (92.3 %) and hydrogen (7.7 %) by weight. The heat is released when the carbon breaks away from hydrogen to combine with O_2 and burn.

$$C_2H_2+O_2 = 2CO+H_2+Heat$$

Depending up on the gas pressure required for welding or cutting oxy acetylene welding is classified into two parts:

Low pressure System and

High-pressure system

Soldering:

Soldering is a method of joining two thin metal pieces using a dissimilar metal or an alloy by the application of heat.

- Temperature is range of 150 to 350 degree.
- Application of flux is externally, usually rosin or borax.
- Soldering application will be electronics circuits.

Advantages of soldering

1) Solder joints are easy to repair
2) Solder joints are corrosion resistance.
3) Low cost and easy to use.
4) Skilled operator is required.

Brazing:

Brazing is a method of joining two similar or dissimilar metals using a special fusible alloy.

The filler metal melts and diffuses over the joint placed.

- The filler metal is called as **Spelters.**
- The flux used is borax or boric acid.
- The brazing is used in copper alloys applications.
- The temperature range is 450 to 900 degree.

Differences between soldering, brazing and Welding

Sl. No.	Welding	Soldering	Brazing
1	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.
2	Temperature required is up to 3800^{o}C of welding zone.	Temperature requirement is up to 450^{o}C.	It may go to 600oC in brazing.
3	Workpiece to be joined need to be heated till their melting point.	No need to heat the workpieces.	Work pieces are heated but below their melting point.
4	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost

			negligible.
5	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.	Cost involved and sill required are in between others two.
6	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.	No heat treatment is required after brazing.
7	No preheating of workpiece is required before welding as it is carried out at high temperature.	Preheating of workpieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.

Module – 5

REFRIGERATION AND CONDITIONING

Refrigeration: Refrigeration is defined as a method of reducing the temperature of a system below that of the surroundings and maintains it at the lower temperature by continuously abstracting the heat from it.

Refrigerant: in a refrigerator, a medium called refrigerant continuously extracts the heat from the space within the refrigerator which is to be kept cool at temperatures less than the atmosphere and finally rejects to it. Some of the fluids like, ammonia, Freon, Methyl chloride, carbon dioxide are the commonly used refrigerants.

Properties of good Refrigerants:

1. Thermodynamic Properties

a. A good refrigerant must have a low boiling temperature at atmospheric pressure.
b. A good refrigerant must have a very low freezing point because the refrigerant should not freeze at low temperatures.
c. In order to avoid the leakage of the atmospheric air and also to enable the detection of the leakage of the refrigerant, both the evaporator and condenser pressures should be slightly above the atmospheric pressure.
d. The latent heat of evaporation must be very high so that a minimum amount of refrigerant will accomplish the desired result in other words, it other words, it increases the refrigeration effect.
e. The specific volume of the refrigerant must be very low. The lower specific volume of the refrigerant at the suction of the compressor reduces the size of the compressor.

Physical properties

A good refrigerant must have low specific heat when it is in liquid state and high specific heat when it is vaporized.

a. The viscosity of a refrigerant at both the liquid and vapour states must be very low as it improves the heat transfer and reduces the pumping pressure.

b. A good refrigerant should be non-toxic,
c. A good refrigerant should be non-corrosive to prevent the corrosion of the metallic parts of the refrigerators.
d. Chemical stability an ideal refrigerant must not decompose under operating conditions.
e. The coefficient of performance of a refrigerant must be high so that the energy spent in refrigeration will be less.
f. A good refrigerant must be odourless, otherwise some foodstuff such as meat, butter, etc. lose their taste.
g. A good refrigerant should have any leakage can be detected by simple test.
h. A good refrigerant must not react with the lubricating oil used in lubricating the parts of the compressor.

List of refrigerants:

1. Ammonia – in vapour absorption refrigerators
2. Carbon dioxide—in marine refrigerators
3. Sulphur dioxide—in house hold refrigerators
4. Methyl chloride—in small scale refrigeration and domestic refrigerators.
5. Freon-12 in domestic vapour compression refrigerators
6. Freon-22 in Air conditioners.

Principle of refrigeration:

In refrigeration, the heat is to be removed continuously from a system at a lower temperature and transfer it to the surroundings at a higher temperature. This operation according to the second law of thermodynamics can only be performed by the aid of the external work. Therefore in a refrigerator, power is to be supplied to remove the heat continuously from the refrigerator cabinet to keep it cool at a temperature less than the atmosphere.

Refrigeration effect: in a refrigeration system, the rate at which the heat is absorbed in a cycle from the interior space to be cooled is called refrigerating effect.

Ton of refrigeration or Ice making capacity: a ton of refrigeration is defined as the quantity of heat absorbed in order to form one ton of ice in 24 hours when the initial temperature of the water is 0^oC.

1 TON of refrigeration = 210 KJ/min = 3.5 KW

Coefficient of performance (COP): The COP of a refrigeration system is defined as the ratio of heat absorbed in a system to the work supplied.

If Q= Heat absorbed or removed, KW

W= work supplied, KW

COP = Q/W

Refrigeration concepts:

1. Heat flows from a system at higher temperature to another at lower temperature.
2. Fluids by absorbing the heat change from liquid phase to vapour phase and subsequently condense by giving off the heat.
3. Heat can flow from a system at low temperature to a system at higher temperature by the aid of external work as per the second law of thermodynamics.

Components of Refrigerator:

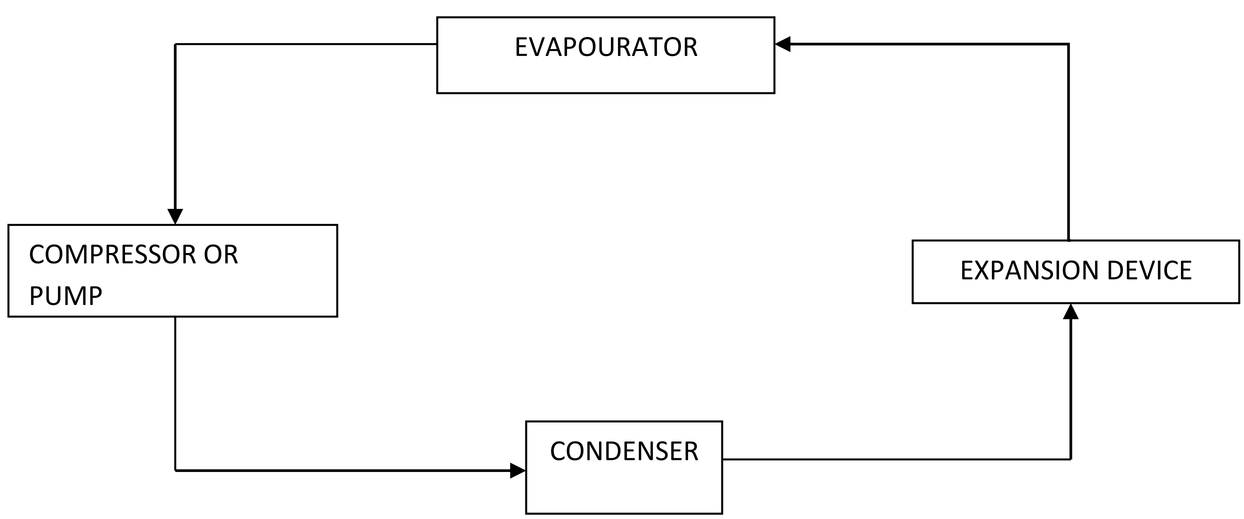


Figure 4.1 Components of Refrigerator

1) **Evaporator:** The evaporator is the heart of the refrigerator where the liquid refrigerant is evaporated by the absorption of heat from the refrigerator cabinet in which the substances which have to be cooled are kept.
2) **Circulating system:** Circulating devices such as compressor or pumps necessary to circulate the refrigerant to undergo the refrigeration cycle.

3) **Condenser:** In a condenser the refrigerant vapour gives off its latent heat to the air and consequently condenses into liquid so that it can be recirculated in the refrigeration cycle.

4) **Expansion device** device to reduce the pressure of liquid refrigerant before passes to the evaporator

Vapour Compression Refrigerator:

The refrigerant at low pressure and low temperature, passing in the evaporator coils, absorbs the heat from the contents in the freezing compartment and evaporates.

The evaporated refrigerant at low pressure from the evaporator is drawn by a compressor. Which compresses it to, high pressure so that the saturation temperature of the refrigerant, corresponding to the increased pressure is higher than the temperature of the cooling medium in the condenser.

The high pressure-high-temperature refrigerant vapour from the compressor flows to the condenser where it gives off its latent heat to the atmospheric air.

As a result of the loss of latent heat in the condenser, the refrigerant condenses.

The high pressure condensed liquid refrigerant approximately at room temperature now flows to the throttle valve in which it expands to low pressure and then passes to the evaporator coils for recirculation once again.

Hence the refrigerant coming out of the expansion valve will be a very wet vapour and at a very low temperature which will be around -10degree. He required low temperature is maintained in the refrigerator by a thermostat switch which switches on and off the compressor motor by a relay as and when the temperature either falls below or rises above the required temperature. The refrigerant is Freon-12

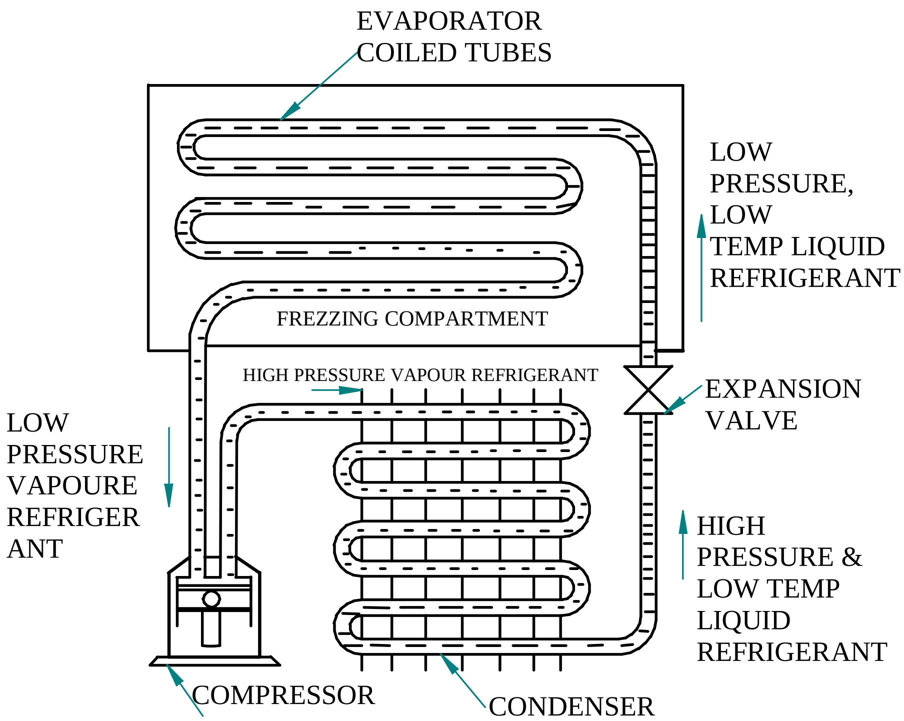


Figure 4.2 Vapour compression Refrigeration

Vapour Absorption Refrigerator:

- The liquid ammonia vapouries in the evaporator coils,
- Absorbing the latent heat from the freezing compartment thus keeping it cool and subsequently gives off heat when it condenses in a condenser.
- Dry ammonia vapour is dissolved in the cold water contained in the absorber, which will produce a strong ammonia solution which is flowing back from the heater-separator from the heat exchanger.
- The worm high pressure strong ammonia solution is passed to the heater-cum-separator provided with the heating coils.

Heating of the high pressure strong ammonia solution will drive out the ammonia vapour from it and consequently the solution in the heater-separator becomes weak which in turn flows back to the heat exchanger. Where it worms up the strong ammonia solution passing through it.

The high pressure ammonia vapour from the heater-separator now passes to a condensed.

The high pressure ammonia liquid is now expanded to a low pressure and low temperature in the throttle valve.

The low pressure condensed ammonia liquid at low temperature is passed onto the evaporator coils provided in the freezing compartment, where it absorbs the heat and evaporates.

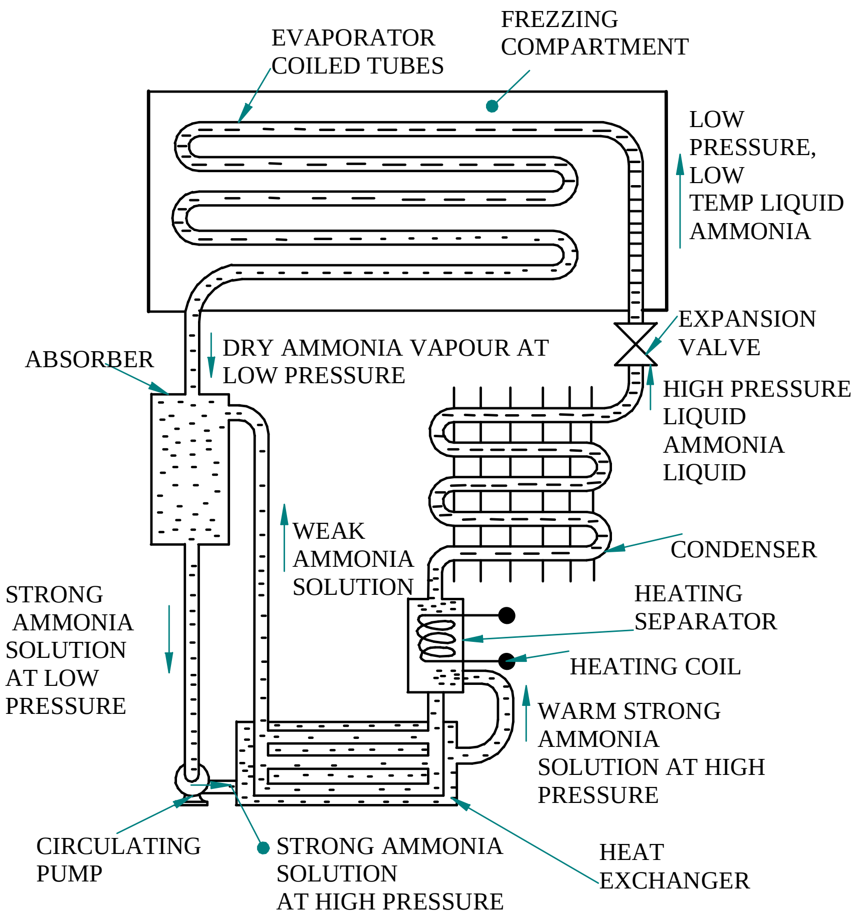


Figure 4.3 Vapour Absorption Refrigeration

Comparison between Vapour Compression and Absorption system:

Absorption system	Compression System
a) Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.	a) Using high-grade energy like mechanical work.
b) Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth.	b) Moving parts are in the compressor. Therefore, more wear, tear and noise.
c) The system can work on lower evaporator	c) The COP decreases considerably with

pressures also without affecting the COP.	decrease in evaporator pressure.
d) No effect of reducing the load on performance.	d) Performance is adversely affected at partial loads.
e) Liquid traces of refrigerant present in piping at the exit of evaporator constitute no danger.	e) Liquid traces in suction line may damage the compressor.
f) Automatic operation for controlling the capacity is easy.	f) It is difficult.

Air-conditioning

Providing a cool constant indoor atmosphere at all times regardless of weather conditions needed either for human comfort or industrial purposes by artificially cooling, humidifying or dehumidifying, cleaning and recirculating the surrounding air is called air conditioning.

Room Conditioner:

The high pressure, low-temperature liquid refrigerant from the condenser is passed to the evaporator coils through the capillary tube where it undergoes expansion.

The evaporator fan continuously draws the air from the interior space within the room through air filler by forcing it to pass over the evaporator coils.

The air from the interior passing over the evaporator coils is cooled by the refrigerant which consequently evaporates by absorbing the heat from the air.

The higher temperature evaporated refrigerant from the evaporator is drawn by the suction of the compressor which compresses it and delivers it to the condenser.

The high pressure, high temperature refrigerant vapour now flows through the condenser coils.

The condenser fan draws the atmospheric air from the exposed side portions of the air conditioner which is projecting outside the building into the space behind it and discharges to pass through the centre suction of the condenser unit over the condenser coils.

The high pressure, high temperature refrigerant passing inside the condenser coils condensers by giving off the heat to the atmospheric air.

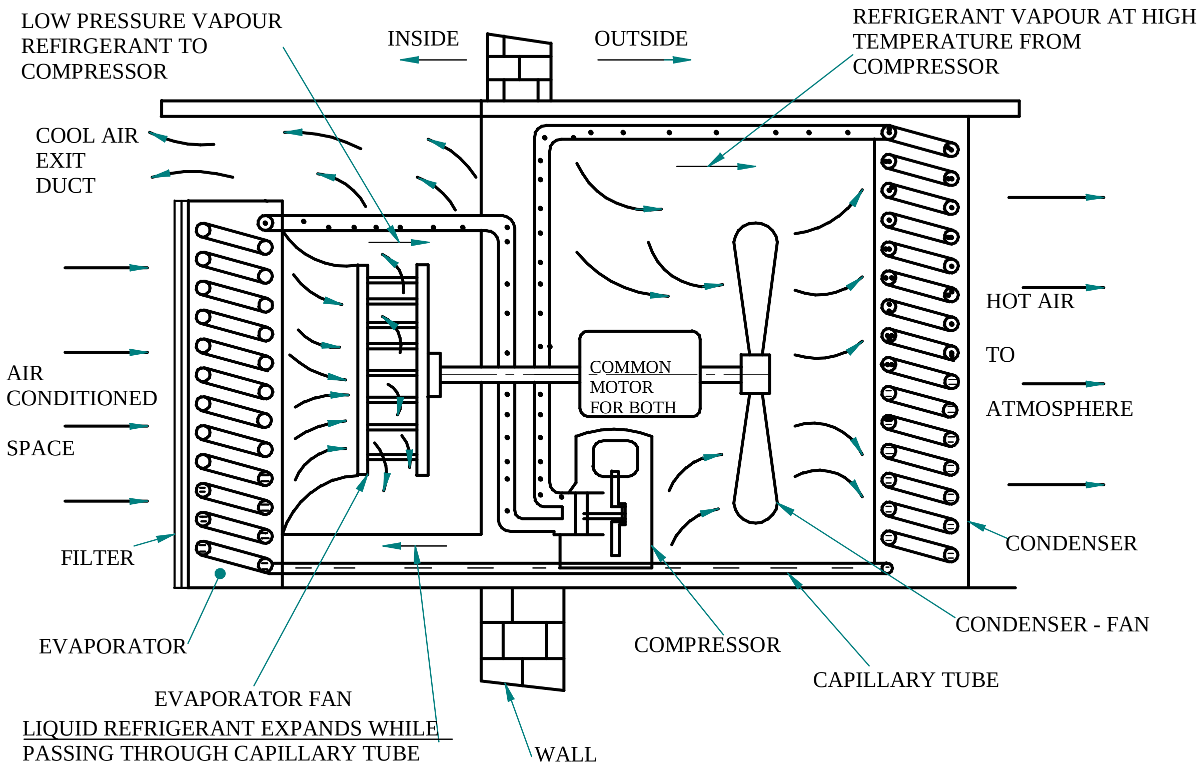


Figure 4.4 Room Air conditioner

Applications of Air-conditioning:

- Aviation industry
- Transportation
- Office applications
- Medical applications
- Agriculture industry